THE WESTERN MARGIN OF THE LOWER MANNVILLE GROUP, LOWER CRETACEOUS, CENTRAL ALBERTA

RONALD LORNE PLATT, B.Sc.

THE UNIVERSITY OF ALBERTA

THE WESTERN MARGIN OF THE LOWER MANNVILLE GROUP, LOWER CRETACEOUS, CENTRAL ALBERTA

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF GEOLOGY

by

RONALD LORNE PLATT, B.Sc.

EDMONTON, ALBERTA

MAY, 1960

ABSTRACT

The lower Mannville group of the upper Pembina River area, about 80 miles west of Edmonton, is correlated with early Lower Cretaceous type Mannville of east-central Alberta. This correlation is based on petrographic and palaeontological evidence, and electric well logs from three wells.

Sediments of the lower Mannville group were derived from slightly metamorphosed sedimentary rocks in the vicinity of the Selkirk Mountains, and deposited in an estuary that was being drowned by the southward transgression of the Clearwater Sea in Albian time.

ACKNOWLEDGEMENTS

The writer wishes to acknowledge the help of Mr. A.R. Nielsen of Mobil Oil of Canada, Limited, Calgary and Mr. P.W.J. Wood of Imperial Oil, Limited, Edmonton who made available the cores used in this investigation.

An expression of appreciation is due all members of the Department of Geology, University of Alberta, for their helpful suggestions and criticisms in various phases of this work. The writer wishes to thank Dr. J.F. Lerbekmo who provided assistance in the petrographic studies, Dr. H. Baadsgaard who made a radioactive age determination on a glauconite sample, and Dr. S.J. Nelson for his part in editing the manuscript. Thanks are also due Dr. C.R. Stelck for the identification of fossils, and especially for the direction and guidance received during the preparation of this thesis. Gratefully acknowledged are the helpful suggestions and criticisms of Mr. G.D. Williams who is completing work on his Ph.D. thesis at the University of Alberta.

The Department of Geology helped financially by paying for the preparation of the thin sections. Miss S. Baker typed the manuscript.

TABLE OF CONTENTS

LIST OF TABLE, FIGURES, AND PLATES

CHAPTER ONE

INTRODUCTION

Purpose and Locale of Study

This study was undertaken to determine the probable source area and environment of deposition of the western margin of the early Lower Cretaceous Mannville group, and to correlate these rocks with those of the type Mannville section which lies approximately 180 miles to the east in the Vermilion area.

The western margin of the Mannville group, as defined here, lies west of the Fifth Meridian from township 46 to township 65, and from range 4 to range 14. The area is shown on Figures 1 and 2, and the generalized stratigraphic section that appears on Figure 3, shows the relationship of the studied interval to the underlying and overlying rocks.

Material and Methods Used

Samples for this study were obtained from Mobil Oil of Canada, Limited and Imperial Oil, Limited. The samples come from stratigraphic intervals cored in the following wells:

(1) Socony Seaboard Violet Grove #7-6.

Lsd. 6, Sec. 7, Twp. 48, Rge. 7, W5M.

K.B.: 2896 feet.

Cored interval: 6530 feet to 6835 feet.

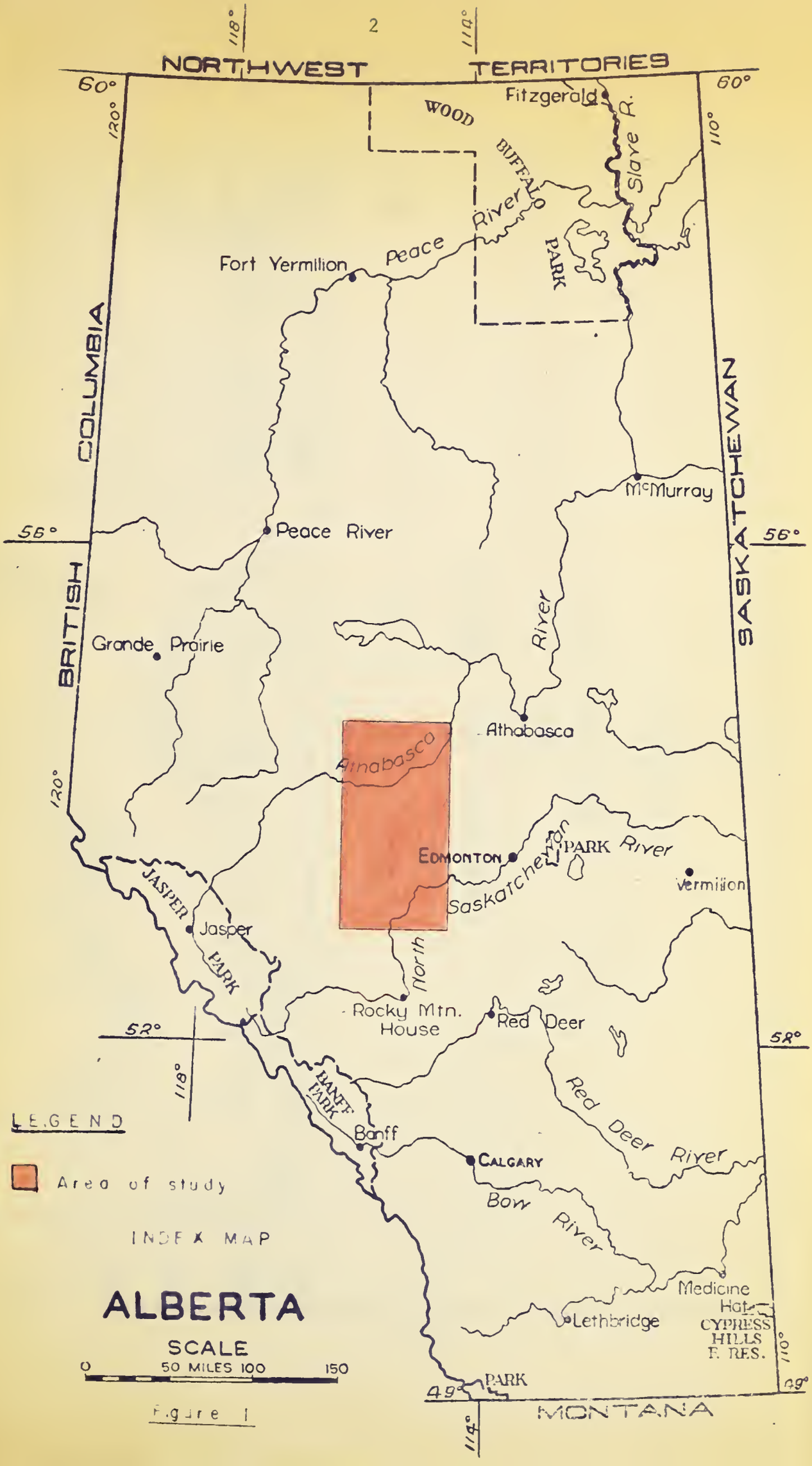

NORTHWEST TERRITORIES
118°
114°
60°
120°
110°
WOOD BUFFALO PARK
Fitzgerald
Slave R.
Peace River
Fort Vermilion
COLUMBIA
BRITISH
SASKATCHEWAN
McMurray
56°
Peace River
Grande Prairie
Athabasca River
Athabasca
Athabasca
EDMONTON
Saskatchewan
PARK River
Vermilion
JASPER PARK
Jasper
North
Rocky Mtn. House
Red Deer
52°
BANFF PARK
Banff
CALGARY
Red Deer River
Bow River
Medicine Hat
Lethbridge
CYPRESS HILLS P. RES.
PARK
49°
MONTANA
LEGEND
Area of study
INDEX MAP
ALBERTA
SCALE
0 50 MILES 100 150

Figure 1

LOCATION OF WELLS

Legend

● Well used in study

Figure 2.

STRATIGRAPHIC SECTION

Socony Seaboard Violet Grove 7-6

Lsd 6, Sec 7, Twp 48, Rge 7 W5M

KB 2895 feet

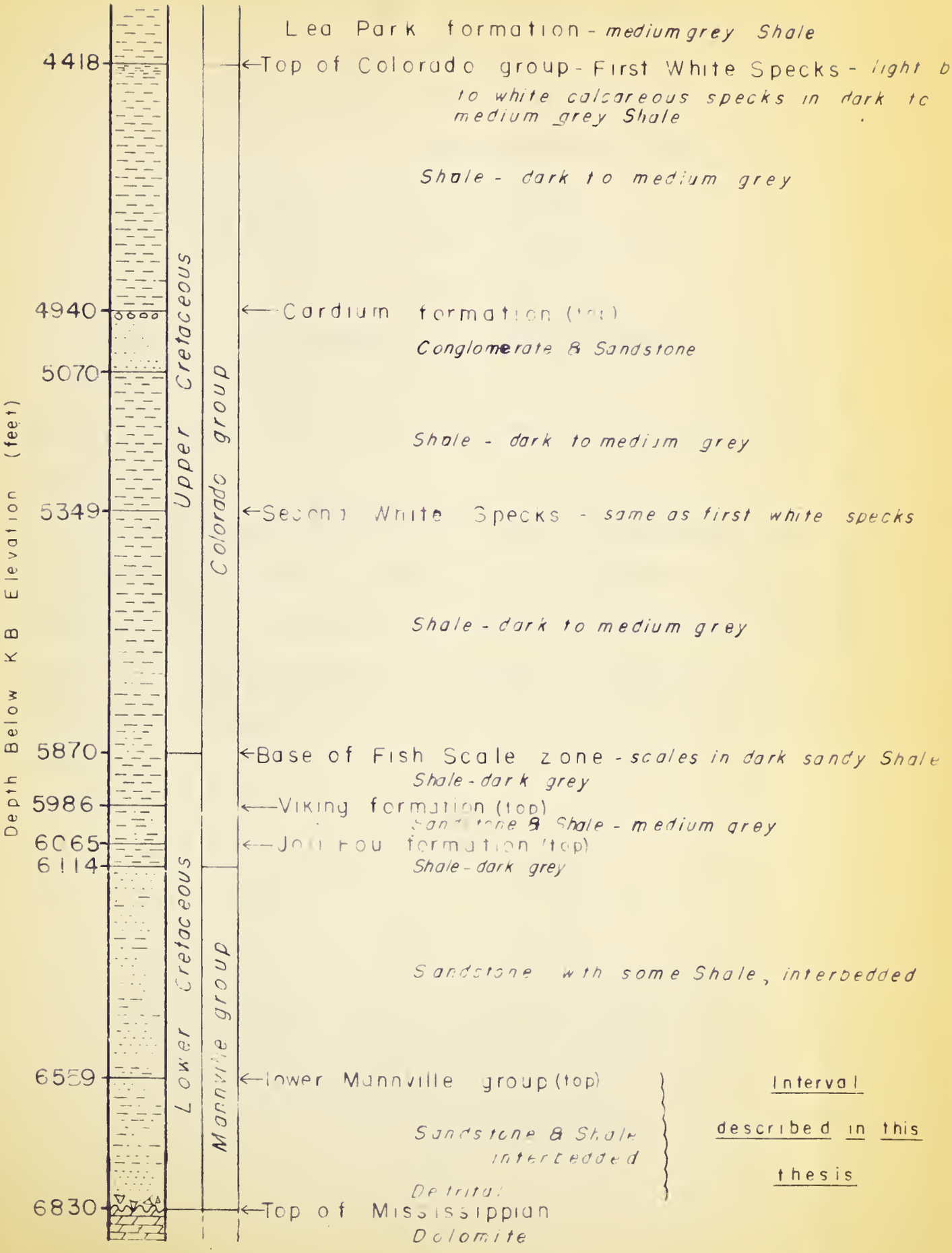


FIGURE 3

(2) Imperial Cynthia #14-28.

Lsd. 14, Sec. 28, Twp. 52, Rge. 11, W5M.

K.B.: 2940 feet.

Cored intervals: 6616 feet to 6650 feet,

6699 feet to 6780 feet.

(3) Imperial Christmas Creek #11-10.

Lsd. 11, Sec. 10, Twp. 62, Rge. 10, W5M.

K.B.: 2817 feet.

Cored interval: 4835 feet to 4965 feet.

In addition, electric well logs from these three wells, and 8 other wells in the area, were used to supplement the data obtained from cores.

Megascopic descriptions of cores were made with the help of a binocular microscope. Megafossils were collected for identification, and shale samples were collected for potential palynological analysis. Appropriate sandstone intervals were sampled for the preparation of thin sections and for heavy accessory mineral separations.

CHAPTER TWO

STRATIGRAPHY

Previous Work

Nauss (1945) applied the name "Mannville formation" to beds in the Vermilion area of east-central Alberta (see Figure 1) which had previously been simply referred to as "the Lower Cretaceous". In the type area these beds are underlain by the pre-Cretaceous unconformity and overlain by dark grey marine shale. He stated (ibid., p. 1609), "the type locality is in the Northwest Mannville well No. 1, between the depths of 1,833 and 2,308 feet." Six members were differentiated locally, mainly on the presence or absence of dark minerals in the sandstones, distribution of marine fossils, and the occurrence of coal seams. Local geographic names were given to each member, which in descending order are:

O'Sullivan member - "Salt and pepper" sandstone; dark to medium grey shale and siltstone with sporadic thin seams of coal; 55 feet thick.

Borradaile member - Quartz sandstone; dark to medium grey shale and buff siltstone; 29 feet thick.

Tovell member - "Salt and pepper" sandstone; dark to medium grey shale and siltstone with a few plant remains; 78 feet thick.

MANNVILLE GROUP NOMENCLATURE, CENTRAL ALBERTA, 1945-1960

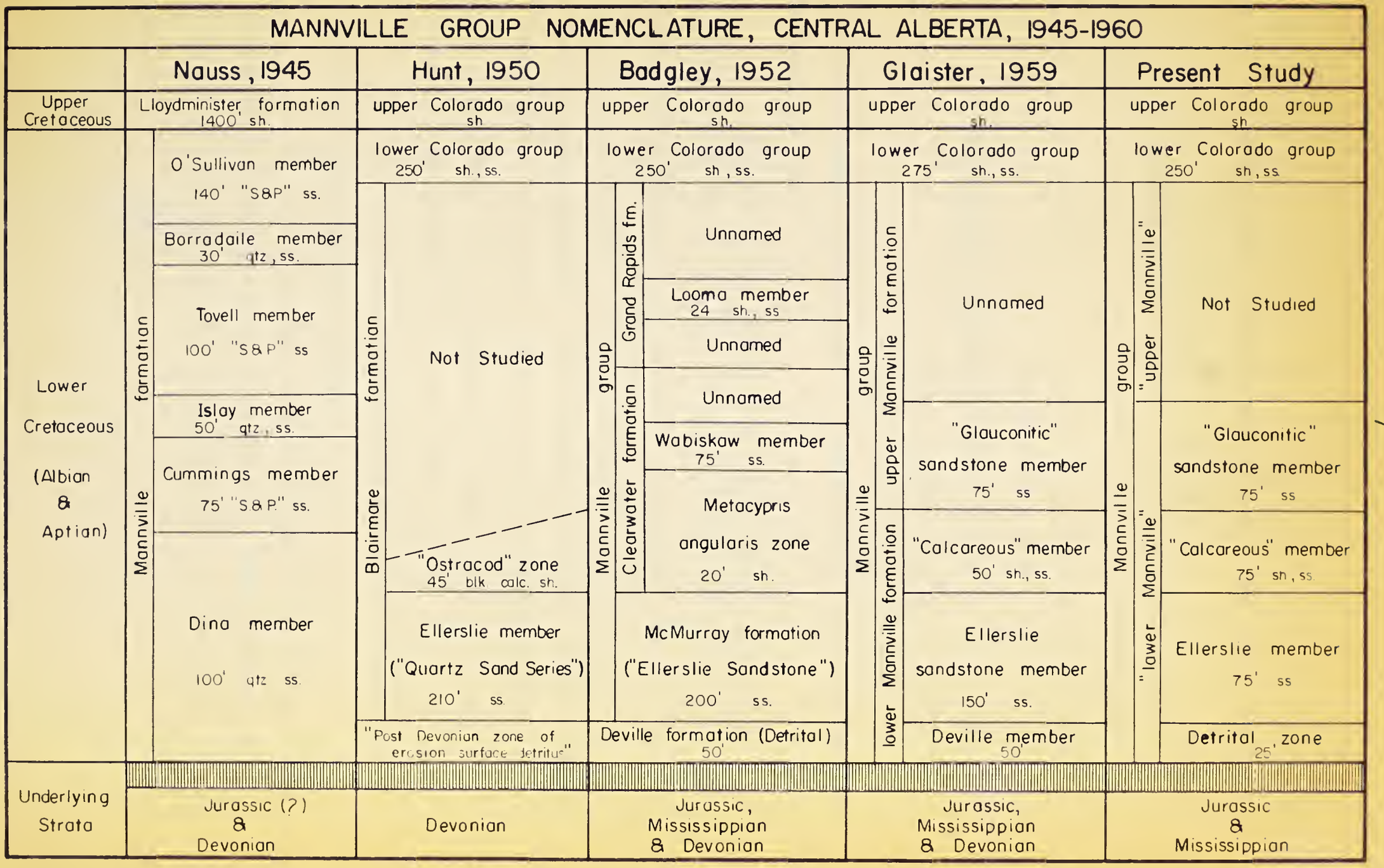


FIGURE 5

Islay member - Quartz sandstone, with some shale partings; 10 feet thick.

Cummings member - Shale; black to dark grey, with some siltstone, "salt and pepper" sandstone, coal, abundant pyrite, and foraminifera; 88 feet thick.

Dina member - Quartz sandstone; dark grey shale, light grey siltstone, siderite nodules, and plant remains; 115 feet thick.

Within the type area the Mannville formation varies in thickness from 250 to 640 feet.

Willson (1947) studied "The Stratigraphy of the Lloydminister and Adjacent Areas", concentrating his investigation on the Mannville formation. He noted that to the west of the type area the Islay member is absent, and that the Cummings and Tovell members cannot be differentiated. Thus he proposed the name "Buffalo Coulee" to be equivalent to Nauss's Cummings, Islay and Tovell members.

Kidd (1948) reported that the Dina member (basal quartz sandstone) was absent from the Beaverhills Lake No. 2 well, which lies about 100 miles west of the type Mannville, but was unable to recognize any of the other members.

For the Lloydminister region, a three-fold division of the Mannville formation was proposed by Wickenden (1948), emphasizing changes in local conditions of sedimentation. His lower unit is

approximately equivalent to Nauss's Dina; the middle unit of marine and brackish water sediments includes most of the Cummings, Islay, Tovell, Borradaile, and a few feet of the O'Sullivan; while his upper unit embraces the remainder of the O'Sullivan member.

In the Leduc oil field (about 20 miles southwest of the city of Edmonton) Lower Cretaceous strata consist of continental to brackish interbedded sandstones, shales, siltstones, coal and carbonaceous beds. Some thin shale bands may be marine in origin. Layer (1949, p. 580) stated that "it is customary to divide these beds into three parts." They are from the youngest to the oldest:

	Thickness (feet)
Coal series	230
Glauconitic sand series	255
Quartz sand series	175-350

Hunt (1950) used the name "Ellerslie member", after the nearby railway siding of Ellerslie, to denote the "Quartz Sand Series" (elsewhere generally referred to as the "Basal Quartz" sandstone) of the Leduc area.

Andrichuk (1949) divided the formation into only two units: lower predominantly marine and brackish beds, and upper continental beds, when he discussed the subsurface stratigraphy of the Majeau Lake No. 1 well, which lies about 45 miles northwest of Edmonton, and is situated near the eastern edge of the present area (see Figure 2). A basal quartz sandstone of the Mannville formation was not recognized in his study area.

Loranger (1951, p. 2350) noted that "the base of the glauconitic sand series", as described by Layer (1949, p. 580), "is marked by dark grey shale in the Leduc area that contains an abundance of ostracods, pelecypods, and gastropods." She referred to this interval as the Metacypris persulcata Peck zone, or "ostracod zone" as it is more commonly known, and suggests that it can be used as a marker horizon over much of Alberta.

In 1952, Badgley raised the "Mannville" to group status, and continued to use it to embrace the same stratigraphic interval in the Vermilion area as originally designated by Nauss (1945). His subdivisions of the Mannville group are shown in Figure 5.

Glaister (1959) integrated the published data with the available subsurface data in his paper on the "Lower Cretaceous of Southern Alberta and Adjoining Areas". He placed the boundary between the upper and lower Mannville formations at the base of the "Glauconitic" sandstone member.

Workman (1959) traced "the widespread occurrence of Glauconitic sand" from a point northeast of Lesser Slave Lake (155 miles north northwest of Edmonton), southward through the eastern part of the present area, to the International Boundary. His line of cross-section closely follows the Fifth meridian.

Description of Stratigraphic Units

A continuous core through the lower Mannville strata was obtained from the Socony Seaboard Violet Grove #7-6 well. With this

core as control and the use of electric well log profiles, lithologic boundaries were determined in the remaining two wells which were not as completely cored. The "salt and pepper", and quartz sandstones, black to grey shales, siltstones, coal, and detritus can be divided into four units, which are from youngest to oldest:

"Glauconitic" sandstone member

"Calcareous" member

Ellerslie member

Detrital zone

Detrital Zone

The name "Detrital zone" has been used to denote the heterogeneous material that overlies the pre-Cretaceous unconformity at the base of the Mannville group, in the study area. To the east, the name Deville formation was applied to a similar unit (Badgley, 1952). It is not certain whether Badgley's unit is correlative with the Detrital zone of the area under consideration, and more data is required to decide the matter.

This zone is present in Imperial Christmas Creek #11-10 and Socony Seaboard Violet Grove #7-6, but is absent from Imperial Cynthia #14-28. In Imperial Christmas Creek #11-10 the contact between the Detrital zone and the Ellerslie member was not observed, but on the basis of electric well log profiles it is probably 5038

feet below the K.B. elevation (see Figure 4). If this interpretation is correct, this unit is 43 feet thick in the Imperial Christmas Creek #11-10 well.

In Socony Seaboard Violet Grove #7-6 this interval is only 5 feet thick and the contact with overlying Ellerslie strata is abrupt.

The unit is composed of angular to rounded fragments (up to 1 inch across) tentatively identified as dolomite, chert, and kaolinitc material, set in a matrix of fine-grained, light grey sandstone. No indication of bedding is present and the sediments appear to have been "dumped" near the source area by forces tending to level-off the pre-Cretaceous topography. As shown on Figure 4, this Detrital zone is present only in the "trough" regions, suggesting that it is very similar to the Deville as used by Badgley (1952), and Glaister (1959).

Ellerslie Member

As mentioned earlier in this chapter, Hunt (1950) was the first worker to use the name "Ellerslie" for the quartz sandstone interval near the base of the Lower Cretaceous in the Leduc area. He stated, "the top of the Ellerslie ('Quartz Sand series') is determined by the first occurrence of vitreous pure-quartz sand or silt below the 'Ostracod zone'." In this thesis the latter is referred to as the "Calcareous" member. Using the above criteria,

the top of the Ellerslie was discerned for each of the three series of cores studied. Recognizable electric well log characteristics support these interpretations.

In each of the study wells, the Ellerslie member overlies the Detrital zone with apparent conformity (where the latter is present) and underlies the "Calcareous" member beneath a relatively sharp contact. This unit thins from 130 feet in Imperial Christmas Creek #11-10 to 47 feet in Imperial Cynthia #14-28.

Sandstones predominate but interbeds of siltstones and shales are common. The sandstones are very fine-to medium-grained, medium to light grey with shades of brown, moderately well sorted, predominantly subrounded, and mainly of the "clean" quartz type, but argillaceous and "salt and pepper" varieties are present. Plant remains are fairly common, but invertebrate fossils are almost completely absent; represented by only two specimens of Scalez, and a few worm burrowings. Locally the sandstones are glauconitic and calcareous, while porosity is either low or absent. The siltstones and shales are mainly dark to medium grey in colour, often carbonaceous, pyritic, micromicaceous, and thinly bedded. Stringers of coal up to 4 inches in thickness occur in Imperial Christmas Creek #11-10 and Socony Seaboard Violet Grove #7-6. A bed of intraformational pebble conglomerate, 4 feet thick, is present 85 feet above the base of the Ellerslie member in the Imperial Christmas Creek #11-10 well (see Plate 3, Figure 2). Interbeds of siltstone and shale,

and finer sandstones are more common in this most northerly well than in the other two. Slickensides were observed in a few shale intervals.

"Calcareous" Member

The naming of this interval follows Glaister (1959) who used it to denote "a rock unit which closely coincides with Metacypris persulcata zone, more commonly known as the 'Ostracod zone' described by Loranger (1951)." It, "is a lithologic unit ... and can be correlated beyond the areal extent of the zone fossil."

The contact with the underlying Ellerslie member is relatively sharp, but the upper boundary is transitional into the overlying "Glauconitic" sandstone member. In Socony Seaboard Violet Grove #7-6, the upper contact was placed at the top of the first horizon of ostracods below the "Glauconitic" sandstone member. The characteristics of the accompanying electric well logs were then utilized to determine this horizon in the two other wells. Ostracods occur immediately below this boundary in Imperial Christmas Creek #11-10, but were not noted any place in this interval in Imperial Cynthia #14-28. The "Calcareous" member is 152 feet thick in Socony Seaboard Violet Grove #7-6, and gradually thins to the north until at Imperial Christmas Creek #11-10 it is only 19 feet thick.

Dark to medium grey limy shales are very common in Socony Seaboard Violet Grove #7-6 but this calcareousness is not apparent in

the two wells farther north in this study area. These shales are generally pyritic, carbonaceous, micromicaceous, fossiliferous (pelecypods, gastropods and plant remains), fairly well indurated, thinly bedded, and commonly grade into siltstones. Cross-bedding, slump structures, evidence of turbulence during deposition, and slickensides were also noted in many of the shale units, which are up to 12 feet thick.

Siltstones, less common than the shales, are mainly medium grey, slightly mottled with darker coloured material, carbonaceous, fossiliferous (plant remains), micromicaceous, pyritic, slightly calcareous, well indurated, and thin bedded. Simple cross-bedding is locally present.

Sandstones are subordinate in Socony Seaboard Violet Grove #7-6, but predominate in the basal 34 feet of Imperial Cynthia #14-28, and occupy 8 of the 19 feet of the "Calcareous" member in Imperial Christmas Creek #11-10. The sandstones are very fine-to fine-grained, poorly sorted, subangular, generally "salt and pepper", medium to light grey in colour, rarely calcareous, rarely glauconitic, and fairly well indurated.

Eighteen inches of very finely crystalline, black limestone, occurs 4 feet below the top of the "Calcareous" member in Socony Seaboard Violet Grove #7-6. A coal seam 1 foot thick lies at the base of this member in Imperial Christmas Creek #11-10. Apparently as a result of this decaying organic matter, pyrite formed beneath

this seam of coal and has almost completely replaced the top 2 inches of the underlying quartz sandstone of the Ellerslie member.

Pelecypods and gastropods abound in the "Calcareous" member in the two southernmost wells, while ostracods are the only invertebrates found in Imperial Christmas Creek #11-10. Several well preserved plant leaves were found 42 feet above the base of the "Calcareous" member in Socony Seaboard Violet Grove #7-6.

"Glauconitic" Sandstone Member

For at least the last decade, the term "Glauconitic" has been used when referring to a series of moderately glauconitic sandstone beds that overlie the "Ostracod zone" in the subsurface of central Alberta. This practice is continued in this thesis.

The gradational lower contact of the "Glauconitic" sandstone member was examined in cores from each of the study wells but the upper boundary could be studied in cores from only the Socony Seaboard Violet Grove #7-6 well. Here it is sharp, between glauconitic sandstone below and black shale above. Electric well log characteristics across this contact were used to correlate this "top" with the two study wells to the north. Its thickness varies from 77 feet (Imperial Christmas Creek #11-10) to 35 feet (Imperial Cynthia #14-28).

Sandstone is the most common rock type in the "Glauconitic" sandstone member, but dark grey shales are present, as are minor amounts of dark to medium grey siltstone. The sandstones are very fine- to medium-

grained, "salt and pepper", medium to light grey, generally glauconitic, and locally very glauconitic, imparting a greenish colour to the rock (e.g. Socony Seaboard Violet Grove #7-6, 6592 feet below K.B.; see Plate 2, Figure 3). They are also slightly pyritic and slightly calcareous in places, moderately well sorted, subangular to subrounded, fairly well consolidated and with either poor porosity or none at all. The shales are often slightly glauconitic, pyritic, micromicaceous, rarely calcareous, and usually thinly bedded.

Beds of coquina (mainly pelecypods and gastropods) up to one foot thick occur in each of the study wells. Plant remains are rare, but pelecypods and gastropods are quite common. A few fish plates, teeth, bones, and scales are also present.

Age

Megafossils were collected from the cores of each of the three study wells. Detrital zone cores were unfossiliferous, Ellerslie cores contained mainly plants, while animals were relatively abundant in the "Calcareous" and "Glauconitic" sandstone members. Depth and identification of specimens collected are listed in Appendix D.

Pelecypods, gastropods, ostracods, and plants constitute the main fossils collected from the lower Mannville strata in the study wells. The composite list of fossils identified by Dr. C.R. Stelck is as follows:

I Animals

(a) Pelecypods:

?Anodonta sp.
?Arctica sp.
Brachidontes sp. cf. B. athabaskensis McLearn
Brachidontes n. sp.
Cardium spp.
Corbula sp. cf. C. palliseri McLearn
Elliptio sp. cf. E. biornatus (Russell)
Elliptio sp. cf. E. hamili (McLearn)
Elliptio sp.
Murraia naiadiformis Russell
Murraia sp. cf. M. naiadiformis Russell
Murraia spp.
Nucula sp. cf. N. athabaskensis McLearn
Nucula sp.
Onestia sp. cf. O. onestae (McLearn)
Onestia spp.
Parmicorbula sp.
Pelecypod, indet.
?Pteria sp.
Sphaerium sp. cf. Eupera onestae (McLearn)
Sphaerium spp.
?Tellina sp.
Thracia sp. cf. T. kissoumi McLearn
Thracia spp.
Unio biornatus Russell
Unio (Pleurobema ?) spp.
Unio spp.
Yoldia sp.

(b) Gastropods:

Campeloma sp.
?Carinulorbis sp.
Goniobasis spp.
Lioplacodes sp. cf. L. bituminus Russell
Lioplacodes spp.
Melania sp. cf. M. multorbis Russell
Melania spp.
Parateinostomata sp. indet.
Scalez sp.
Viviparus sp. aff. V. murraiensis Russell
Viviparus spp.

(c) Arthropods:

Estherid? A
Ostracods

(d) Miscellaneous:

Cycloid scale.
Fish plate, scales, teeth, and bones.
Worm burrowings.

II Plants

Athrotaxites sp. cf. A. berryi Bell
Carpolithus sp.
Elatides splendida Bell
Elatides sp.
Equisetum sp.
Ginkgo sp.
Nilssonia sp.
Pityophyllum nordenskioldi (Heer)
Podozamites sp. cf. P. stenopus Lesquereux
Podozamites spp.
?Pterophyllum sp.
?Ruffordia sp. cf. Sphenopteris gopperti (Dunker) Seward
Sphenopteris sp. cf. S. latiloba Fontaine
Fossil wood.
Piece of fossil bark.
Plant remains, indet.
Wood fragments.

Murraia naiadiformis, Unio biornatus, Goniobasis? multicarinata, Lioplacodes bituminis, Melania multorbis and Viviparus murraiensis have been described from the McMurray formation by Russell (1932). Brachidontes athabaskensis, Nucula athabaskensis, Onestia onestae, and Thracia kissoumi were described by McLearn (1919, 1931, 1933) as occurring in the Clearwater shale

which overlies the McMurray formation. A similar suite of fossils was found by Andrichuk (1949) in cores from the Majeau Lake area.

Except for Carpolithus, each genus of plants of the above composite list has been described from the lower Blairmore group of southern Alberta by Bell (1956).

Mellon and Wall (1956) lithologically correlated the McMurray formation top with the top of the Dina member of the Mannville formation, inferring that this boundary is diachronic. However they considered the McMurray top the older and on the basis of microfauna placed the upper part of that formation in the lower part of the Middle Albian substage of the Lower Cretaceous. This evidence indicates an Albian age for the "Calcareous" and "Glauconitic" sandstone members of the present area. A few well preserved plant fossils were collected from the Ellerslie member of Imperial Christmas Creek #11-10 and Socony Seaboard Violet Grove #7-6, and also 42 feet above the base of the "Calcareous" member in Socony Seaboard Violet Grove #7-6. Plants similar to these have been placed in the Aptian stage by Bell (1956) but they are long ranging genera, extending from Jurassic through to Lower Cretaceous time.

A Cretaceous age for the intervals studied in Socony Seaboard Violet Grove #7-6 and Imperial Christmas Creek #11-10 was supported by N.P. Elphinstone (personal communication) on the basis of palynological evidence, but he suggested that part of the section in Imperial Cynthia #14-28 is Jurassic in age, or at least pre-Mannville (see Figure 4). Petrographic evidence and a comparison of

electric well log profiles in addition to evaluation of associated megafauna, leads the writer to disagree with Elphinstone's suggestion with regard to the Imperial Cynthia #14-28 well.

Several specimens of gastropod opercula (Scalez) were found, but they could not be used for correlation. It is very likely that in earlier studies such fossils have been misidentified as "fish scales".

From the evidence given above, organic remains in the lower Mannville sediments of the present area are believed to be Aptian and Albian in age.

A glauconite sample, taken from 33 feet below the top of the "Glauconitic" sandstone member in Socony Seaboard Violet Grove #7-6, was submitted to Dr. H. Baadsgaard of the Geology Department, University of Alberta, for the determination of an absolute age. His findings indicate that the sample is 75 million years old. This date does not coincide with the currently accepted age for these strata (H. Baadsgaard, personal communication).

Correlation

Lithologic criteria were used for correlation, utilizing petrographic evidence and electric well log profiles. The rock-stratigraphic units were equated with similar intervals to the east which have been studied by other writers (Badgley, 1952; Glaister, 1959; G.D. Williams, personal communication).

Based on lithologies and general stratigraphic position the Detrital zone of the present area is equated with the Deville as used

by Badgley and Glaister. The Ellerslie member is believed to be the correlative of Badgley's McMurray formation and Glaister's Ellerslie sandstone member, but the top is considered to be slightly older than the top of the Dina of type Mannville. The "Calcareous" member of the present area occupies the same stratigraphic position as Glaister's "Calcareous" member, but it may not be directly correlative to the Metacypris angularis zone as designated by Badgley. The tops of the writer's "Glauconitic" sandstone member, Badgley's Wabiskaw member, Glaister's "Glauconitic" sandstone member, and the Islay of type Mannville are considered to be correlative. The stratigraphic cross-section (Figure 4) also relates the Ellerslie, as observed in the three study wells, to the Ellerslie type area. The writer feels justified in using the name "Ellerslie" to denote the unit of predominantly "clean" quartz sandstone that overlies the Detrital zone and underlies the "Calcareous" member on the western margin of the lower Mannville group.

As defined here, the lower Mannville sediments do not coincide with Glaister's (1959) lower Mannville formation (see Figure 5). The present writer has divided his upper and lower units at the top of the "Glauconitic" sandstone member, inasmuch as the latter contact is better defined in the study area.

Faunal evidence indicates that the interval studied has age affinities with the McMurray formation and a portion of the Clearwater formation of east-central Alberta, and with the lower Blairmore group of southern Alberta.

CHAPTER THREE

PETROGRAPHY OF THE SANDSTONES

Sample Locations and Preparation

Twenty-three uncovered thin sections were prepared by a petrographic section service company. Samples were selected from several different lithologies in the three wells: "clean" quartz sandstone, "salt and pepper" sandstone, "glauconitic" sandstone, siltstone, and a specimen from an intraformational conglomerate (Imperial Christmas Creek #11-10). Distribution of thin sections from the three wells are as follows:

Imperial Christmas Creek #11-10 -------- 7 thin sections

Imperial Cynthia #14-28 ---------- 4 thin sections

Socony Seaboard Violet Grove #7-6 ------12 thin sections

Depth of each sample is given in Appendix B.

Prior to microscopic examination, the slides were subjected to the feldspar staining technique described by Hayes and Klugman (1959) in which potash feldspar is stained yellow by sodium cobaltinitrite. It was found later that some of the clay minerals also stained differentially, for according to Krumbein and Pettijohn (1938), kaolinite absorbs dyes very strongly.

Textures

A. General Description of Thin Sections

In the main, structures are not apparent, however a few specimens show stratification by alignment of dark coloured matter or concentration of finer material. Ellerslie member samples are in general closely packed while those stratigraphically above are less well packed. Detrital contacts range from tangential (essentially no interpenetration) to sutured (extreme interpenetration) with straight (slight interpenetration) and concavo-convex (moderate interpenetration) types being the more common.

Grain sizes vary from 0.06 to 0.60 mm. (i.e. silt-size to medium sand-size) with most of the samples being very fine to fine-grained (0.10 to 0.20 mm.). Wentworth's Particle Size Classification (Krumbein and Sloss, 1956, p. 71) was followed.

Grain roundness ranges from well rounded to angular. The Ellerslie member has predominantly subrounded grains, while above, in the "Calcareous" and "Glauconitic" sandstone members, subangular particles are most common. A similar division can be observed in the sorting properties of the rocks. The lower member is moderately well sorted to well sorted while the two overlying units are rather poorly sorted.

The argillaceous rock fragments (i.e. shale, siltstone, phyllite, and schist) are more angular and slightly larger than either the quartz or chert particles, and usually are elongate. Many

are relatively hard and some show alignment of the phyllosilicate minerals. A considerable amount (25 to 50 per cent) of the quartz particles show undulatory extinction to some degree, with many extensively strained.

Porosity is low (generally less than 2 per cent) or absent; due to the close-packed nature of the grains and micro-stylolitic contacts, or the abundance of cement (carbonate and silica) and/or matrix.

B. Microstylolites

In the last 40 years much has been written concerning the origin of stylolites. Early studies were concerned with structures of megascopic dimension in carbonate rocks. Stockdale (1922, 1926) advanced his "pressure-solution theory" which closely follows Reicke's principle (Harker, 1939) that is well founded in metamorphic geology. An alternate theory of "pressure-contraction" was postulated by Shaub (1939, 1949) in which he contended that stylolites originate in unconsolidated sediments. The differences in these theories are fundamentally: (a) whether or not stylolites are primary or secondary structures and (b) whether or not there is actual removal of material at the site of the stylolites. The former theory has received most support.

More recently, similar structures of microscopic dimensions (microstylolites) have been reported by Sloss and Feray (1948) from

grain boundaries in the chert facies of the Cut Bank sandstones of Montana. This and subsequent studies (Heald, 1955, 1956, 1959; Thomson, 1959; Golding, 1959) have concerned themselves with the effect the development of microstylolites have on the porosity and permeability of neighboring rock.

Heald (1955) suggested that a film of clay around detrital grains acts as a catalytic promoter of solution, thus initiating interpenetration of the particles.

The present writer has recognized microstylolites in some of the Socony Seaboard Violet Grove #7-6 samples. Some occur as "seams" (slides 4191 and 4192) but most are confined to contacts between grains (slides 4183 and 4184) (see Plate 5, Figures 4 to 12 inclusive). They are best developed parallel to the bedding, although random orientations occur. Previous studies have described quartz-quartz (e.g. Heald, 1955, 1956, 1959; Thomson, 1959; Golding, 1959), chert-quartz, and chert-chert contacts (Sloss and Feray, 1948). The writer has observed the strongest development of microstylolite contacts between quartz grains and argillaceous rock fragments (shale, etc.), and between grains of argillaceous rock. Concentration of dark brown opaque material (insoluble residue?) can be detected at all contacts except where one unit is dark carbonaceous shale (see Plate 5, Figure 6). Individual columns attain a length of 0.20 mm.

Argillaceous rock fragments commonly interpenetrate with quartz grains (see Plate 5, Figure 8) without evidence of distortion

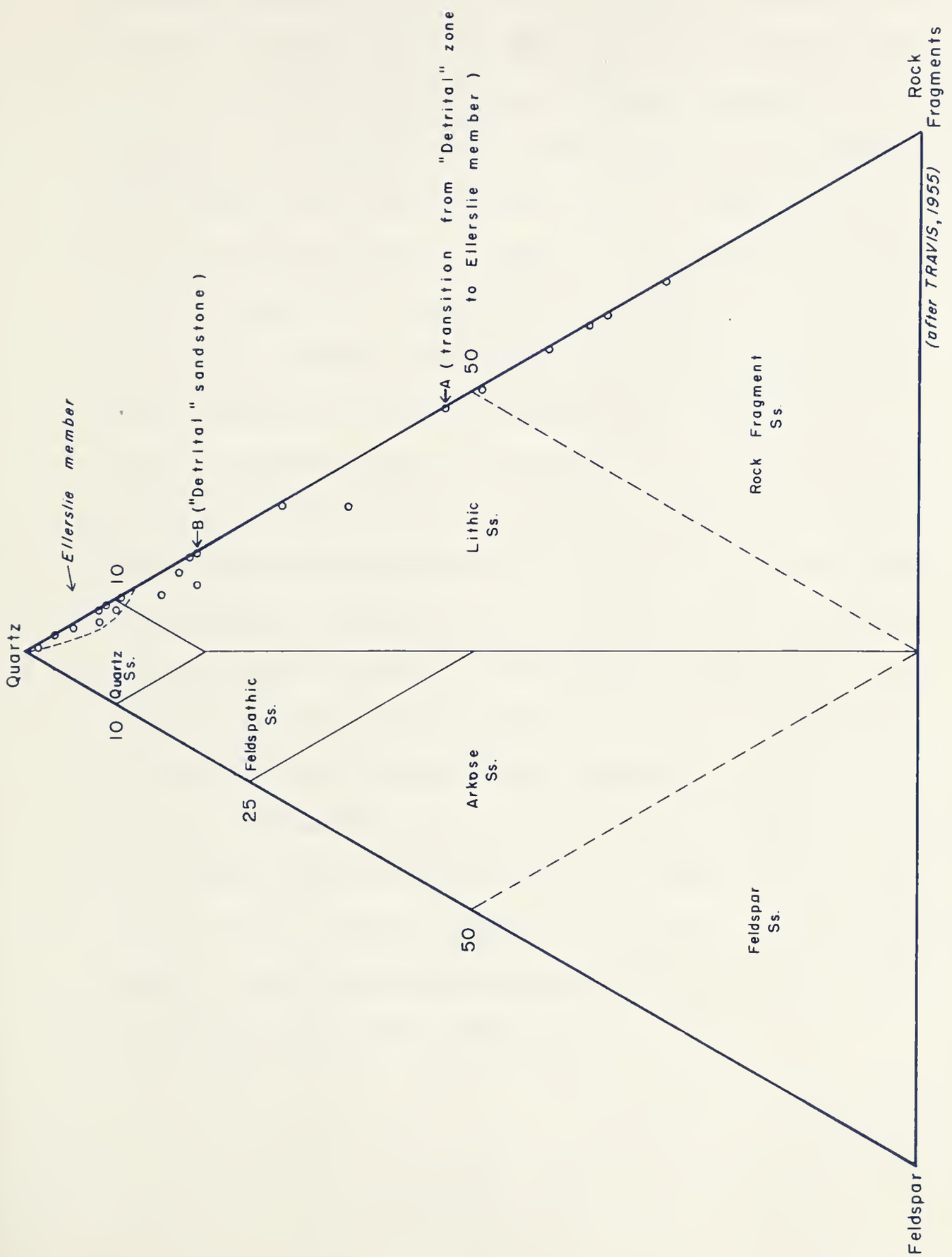
in either particle. Thus differential solution has taken place without crushing or replacement. It appears as if the rock fragments have penetrated the quartz farther than they have themselves been penetrated, but rock fragments appear to permeate each other about equally (see Plate 5, Figures 7 and 12). This can be accounted for by Heald's (1955) determination of relative solubility of minerals under stress in sandstone. According to decreasing solubility, the order is: (1) calcite, (2) quartz, (3) feldspar, (4) mica and clay minerals, (5) collophanite, sphene, and tourmaline, (6) zircon and pyrite. Pressure of overlying sediments would have to be sufficient to keep the dissolving particles in contact with each other, but Heald (1955) did not think that the thickness of the overburden needed to be great. Porosity is lost as the grains penetrate one another and by the precipitation of the dissolved material in pore spaces. According to Sloss and Feray (1948) all of the cement need not be deposited near by but may move for some distance laterally or vertically. Considerable vertical movement may have occurred in the vicinity of the Socony Seaboard Violet Grove #7-6 well. Here, the Ellerslie member has many authigenic quartz overgrowths (see Plate 5, Figures 1 and 2) while the overlying member contains an abundance of well developed microstylolites. It is perhaps significant that in the other two wells microstylolites were not observed and the Ellerslie member had up to 5 per cent porosity.

The force that initiated the formation of these stylolites is not clearly understood. Possibly a favorable combination of pressure of overlying sediments and the presence of the correct type of clay produced the conditions necessary for formation of stylolites. Such a mechanism has been fully described elsewhere (Thomson, 1959).

Composition and Classification

Travis's (1955) classification was used in this investigation. It includes chert with the rock fragments thus differing from most contemporary classifications. However, his names for the different sandstones are similar to those used by other writers (see Figure 6). The term "argillaceous" is added when the matrix comprises 10 per cent or more of the rock. Arbitrarily, the present writer placed the boundary between matrix and "normal" detrital particles at one-tenth the average size of the larger size fraction.

On the triangular classification diagram (Figure 6) the samples plot along one side due to the paucity of feldspar. Generally Ellerslie member specimens plot high in the "quartz" apex and are therefore classified as quartz sandstones, with some ranging to quartz-rich lithic sandstones. Although the break between the Detrital zone and the Ellerslie member appears sharp in the Socony Seaboard Violet Grove #7-6 well, a sample (slide 4191) taken from just above this break contains a high percentage of rock fragments (A, Figure 6), indicating that the compositional change is transitional. Post-



COMPOSITION OF SANDSTONES IN THE LOWER MANNVILLE GROUP

FIGURE 6

Ellerslie specimens are lithic and rock fragment sandstones with the "Calcareous" member having the greater abundance of rock fragments.

Four thin sections of rock fragment sandstones from the "Calcareous" and "Glauconitic" sandstone members were studied in detail using a Swift Automatic Point Counter. These rocks are composed of about 25 per cent quartz, 25 per cent siliceous rock fragments, 25 per cent argillaceous rock fragments, 10 per cent matrix and 15 per cent cement. Many of the quartz grains show strain shadows. Four types of siliceous rock fragments (i.e. "normal", coarse-grained, and coloured chert; and metaquartzite particles) and four varieties of argillaceous rock fragments (i.e. shale, silty and carbonaceous shale, phyllite or argillite) were differentiated. The matrix consists of fine quartz and chert particles, while the cement is mainly carbonate with silica overgrowths on some of the quartz grains. These rocks are generally loosely packed with straight (slight interpenetration) detrital contacts. Bedding is faintly preserved in some of these sandstones by alignment of dark coloured material and subparallel position of elongate grains. Porosity averages 3 per cent in the thin sections examined. A more complete description of these four thin sections can be found in Appendix C, page XXXVII.

Heavy Accessory Minerals

A. Sample Locations and Preparation

Heavy accessory minerals of the lower Mannville group were extracted from sixteen samples, representative of a total cored interval of 543 feet. Seven samples were from Socony Seaboard Violet Grove #7-6, four from Imperial Cynthia #14-28, and five from Imperial Christmas Creek #11-10. Depths of these are given in Appendix B.

About 300 grams of each specimen were put through a jaw crusher, then manually ground on a buckingboard until the sample passed through a U.S. Standard 35 mesh sieve, and sieved for twelve minutes on a sieve shaker. The -80+230 fraction (U.S. Standard Sieve Series) was washed with tap water to remove clay and water solubles, and then acidized with 5 per cent HCl to further cleanse the grains before the heavy minerals were removed.

A standard procedure was followed to make the heavy accessory mineral separation using acetylene tetrabromide ($C_2H_4Br_4$; specific gravity 2.96 at 20°C.). Aroclor (n=1.66) was used to make permanent mounts.

Upon examination of the original mounts it was noted that there were numerous rock fragments and a preponderance of opaque minerals, (mainly pyrite) in many of the slides, as high as 95 per cent in one. In some, notably those samples from Imperial Cynthia #14-28 (code number MCA), a high percentage of siderite was present. To remove some of these unwanted components the remaining portion of

each heavy accessory mineral fraction was placed in a 500°C oven for five minutes in order to magnetize the pyrite and siderite. Subsequently each sample was run through a Frantz Isodynamic Separator and a portion of the non-magnetic fraction mounted in aroclor. Most of the pyrite and siderite had been removed.

When possible, two hundred non-opaque grains were counted on each slide, but due to the abundance of rock fragments fewer than this number were present on some. Relative percentages of non-opaque and opaque minerals were visually estimated using the first set of mounted slides. The results are shown on Table 1.

Photomicrographs of some of the heavy accessory minerals present in the lower Mannville in the study wells are shown on Plate 6.

B. Description of Non-Opaque Heavy Accessory Minerals

The following non-opaque minerals occur in the suite of heavy accessory minerals:

Apatite
Barite
Collophane
Rutile
Siderite
Tourmaline
Zircon

Apatite

This mineral ranges from 0 to 45 per cent of the total detrital non-opaque heavy accessory mineral assemblage. In the basal portions of the three sections studied it is present in small amounts, but at the top of each unit, apatite makes up a major share of the heavy mineral suite (see Figure 7). Grains are colourless, generally anhedral subangular. Some are subrounded and a few angular (from crushing?). Inclusions occur in the majority of the fragments, ranging in outline from acicular to circular (Plate 6, Figures 1b and 1c).

It seems likely that most of these fragments are first cycle, especially those constituting the larger amounts near the top of the intervals. Possible sources are: igneous rocks and crystalline schists, limestones, and argillites.

Barite

Barite, presumed to be authigenic, was not counted with the non-opaque minerals, but only noted. It is present in most of the samples as anhedral, subangular grains characterized by very low birefringence, good cleavage, and incomplete extinction. Some grains contain irregular carbonaceous inclusions. Detailed examination with a series of immersion oils indicated this to be a strontium-rich variety.

Collophane

This mineral was identified in only a few samples, most notably in the Imperial Cynthia #14-28 specimens, and not exceeding a few per cent of the non-opaque minerals. Colour varies from yellow-brown to almost black, appearing speckled under plane polarized light, and isotropic, or weakly anisotropic under crossed nicols. Speckling may be haversian canals or lacunae. Grains are subangular to subrounded in shape, and may be present in the sediments as fragments of organic structures.

Rutile

Rutile is present in all samples, making up 17 per cent of one specimen (Imperial Cynthia #14-28; MCA-2), and is remarkably uniformly distributed vertically in the intervals of interest. Yellow-brown, and deep red-brown coloured varieties are present, with the former the more common of the two. Rounded elongate types are the predominate shape, but stubby rounded to subangular particles are not uncommon. The colour and very high birefringence are most distinctive. Knee-shaped twins are rare but a few were observed. Dominantly rounded particles are indicative of several cycles of erosion and deposition, however several angular subhedra were observed (see Plate 6, Figure 3c).

Siderite

Distribution of siderite is sporadic, but most common in the Imperial Cynthia #14-28 samples. In one (MCA-2) it makes up approximately 80 per cent (visual estimation) of the mounted particles. Clear to grey in colour, commonly with tiny irregular brown-grey spots or dust-like inclusions (alteration ?), the grains are anhedral, subangular to angular, with a high index of refraction, extremely high birefringence, and uniaxial negative figure. Siderite is here considered to be authigenic.

Tourmaline

This mineral is one of the two most common non-opaque detrital heavy accessory minerals present in the samples studied. It is present in all of the specimens, ranging from 1 per cent (Socony Seaboard Violet Grove #7-6; SVG-4) to 75 per cent (Imperial Cynthia #14-28; MCA-17) of the non-opaque detrital fraction.

Four varieties of tourmaline were identified on the basis of colour alone, these being: blue-grey, brown, green, and olive, although a gradation of one colour into the other is evident. All have been extensively abraded, causing the grains to be subrounded to well rounded, and occasionally almost spherical with only a few particles exhibiting any crystal form. The grain morphology is thus indicative of several depositional cycles.

A colourless overgrowth was observed on only one grain, this in turn being well-abraded, indicating that this grain too has survived at least two cycles of erosion.

Inclusions are sporadic in concentration, but occur in all four varieties. No basis for correlation, using types or amount of inclusions could be employed, as these vary irregularly within each variety.

Zircon

Like tourmaline, zircon is present in all samples, making up from 14 to 57 per cent of the non-opaque detrital heavy accessory minerals. All grains are colourless, very rarely zoned, and with minor exceptions show evidence of being extensively abraded. Well rounded, rounded and subrounded grains dominate, while angular fragments and relatively small euhedra of zircon are rare. The angular fragments may be the result of crushing methods as they exhibit no indications of abrasion. Using the above morphological criteria, three types of zircon were differentiated:

(1) Rounded and well rounded,

(2) Subrounded,

(3) Others.

Rounded grains usually exhibit some definite elongation whereas the well rounded types are nearly spherical. All subrounded grains are elongate and some show one or more, only slightly abraded crystal

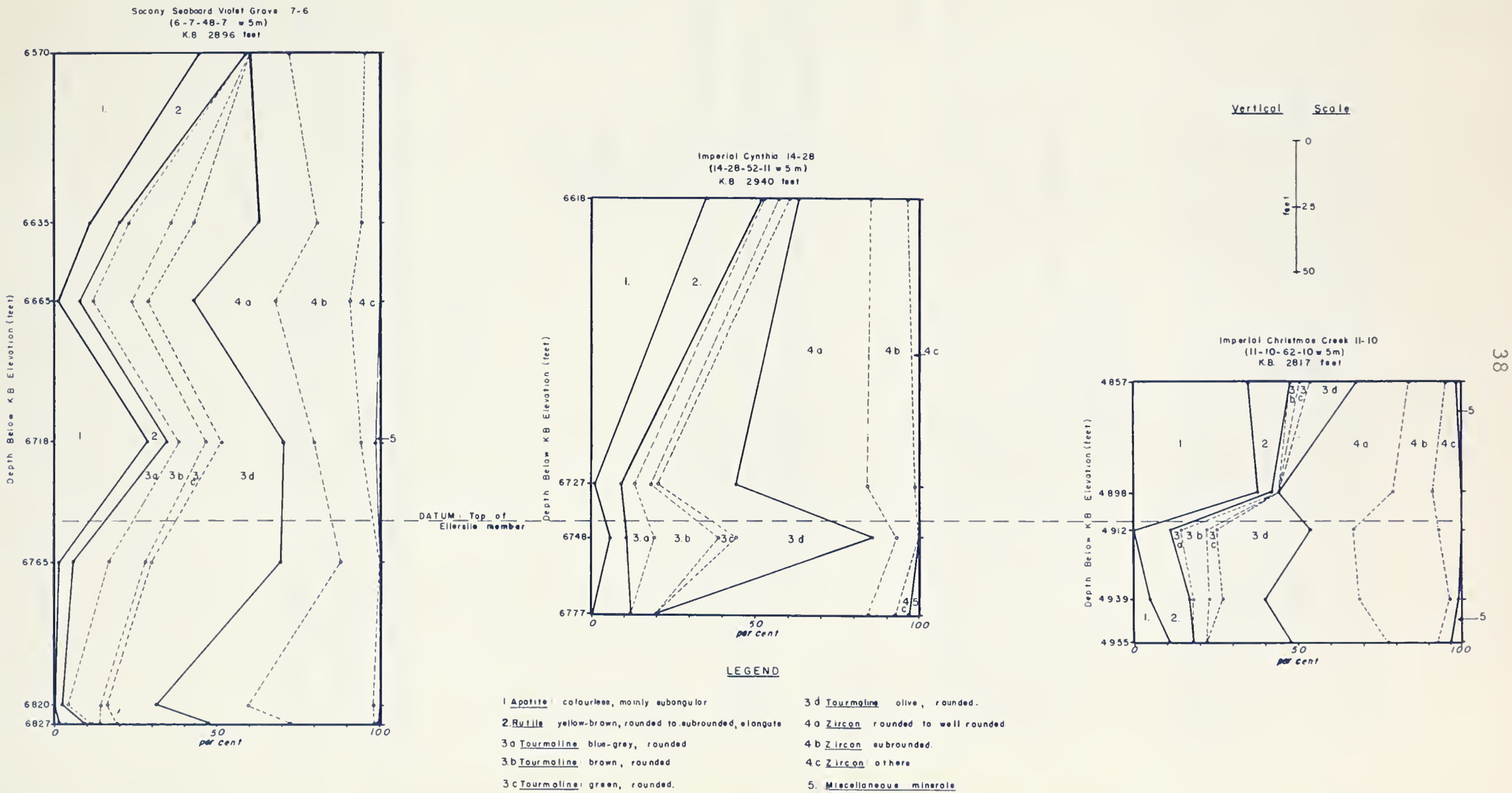
RELATIVE ABUNDANCE OF HEAVY ACCESSORY MINERALS IN THE LOWER MANNVILLE GROUP

Heavy Minerals	SVG-4	SVG-11	SVG-14	SVG-16	SVG-26	SVG-36	SVG-39	MCA-2	MCA-12	MCA-17	MCA-23	MXC-2	MXC-10	MXC-14	MXC-18	MXC-22
Non-opaque	20	80	40	20	25	20	50	95	95	30	15	20	25	40	5	10
Opaque	80	20	60	80	75	80	50	5	5	70	85	80	75	60	95	90
Apatite	C	C	Tr	R	Tr		Tr	C	R	R		C	C		Tr	R
Barite	R	C	R	R		R	C			R		R	R	R		
Collophane					R			R	R	R	R					C
Rutile	C	C	C	Tr	R	Tr	C	R	R	R	R	C	Tr	C	R	R
Siderite				C				A	A	C	C		R	R		
Tourmaline	Tr	A	C	C	C	C	C	R	C	C	R	C	Tr	C	R	C
Zircon	C	A	A	C	C	C	A	C	C	C	C	C	C	C	C	C
Miscellaneous				Tr			Tr	R	Tr		R	Tr			Tr	Tr
Hematite	C		C				C					C		C	C	C
Leucoxene	C	C	C		C	C	C	R	R	C	C	C			C	C
Pyrite	A	C	A	A	A	A	A	C	R	A	A	A	A	A	A	A

A-abundant (20% or more), C-common (3% to 20%), R-rare (1/2% to 3%),
Tr-trace (0 to 1/2%)

Location of samples given in Appendix B.

TABLE 1.



LEGEND

1 Apatite colourless, mainly subangular

2. Rutile yellow-brown, rounded to subrounded, elongate

3a Tourmaline blue-grey, rounded

3.b Tourmaline brown, rounded

3 c Tourmaline green, rounded.

3 d Tourmaline olive, rounded.

4 a Zircon rounded to well rounded

4 b Zircon subrounded.

4 c Zircon others

5. Miscellaneous minerals

DISTRIBUTION OF HEAVY ACCESSORY MINERALS IN THE LOWER MANNVILLE GROUP

FIGURE 7.

faces, and are therefore subhedral. This subhedral group was not large enough to be differentiated as a fourth type.

Inclusions, observed in members of all three types, are insignificant in amount, with many grains entirely inclusion free.

Miscellaneous

In the sixteen samples examined, tentative identification of other mineral grains were made, including biotite, brookite, monazite, and spinel. Only a grain or two of each was found on any one slide.

C. Description of Opaque Heavy Accessory Minerals

Opaque heavy accessory minerals of the following types were identified in the suite of heavy accessory minerals:

Hematite

Leucoxene

Pyrite

Hematite

This mineral occurs as a minor constituent in approximately half of the samples, and is present as small subangular bright red particles. Some of the pyrite-quartz aggregates and other rock fragments are hematite stained.

Leucoxene

Leucoxene is present as rounded and subrounded, white to yellowish white grains. It is present in all but a few samples, often comprising 10 to 15 per cent (visual estimation) of the mounted grains.

Pyrite

Each mount contained some pyrite while many were dominated by it (2 to 90 per cent; visual estimation). It occurs commonly as irregular clusters of small particles, rarely as individual grains, but prevalent as aggregates intimately associated with quartz. A small amount of clinging pyrite is sufficient to pull quartz down with the heavy concentrate during the separation process. It appears that most, if not all pyrite present is authigenic.

CHAPTER FOUR

PROVENANCE AND ENVIRONMENT OF DEPOSITION

Using data presented in earlier chapters of this thesis, some conclusions pertaining to the nature of the source material, source area and depositional environment can be drawn.

Source Material

Thin sections of sandstones of the lower Mannville group show that argillaceous rock fragments, particles of chert, and metaquartzite fragments are major constituents of some of the rock-stratigraphic units. It is these fragments that impart the "salt and pepper" aspect to much of the lower Mannville.

Argillaceous fragments make up to 25 per cent of the "salt and pepper" zones of the sandstones. Of this fraction, dark brown to almost opaque, carbonaceous shale is commonly the most abundant, although medium grey clay shale fragments occasionally predominate. Medium grey silty shale is usually subordinate. Some argillaceous particles are fairly micaceous and appear to be somewhat recrystallized. Such particles have been tentatively identified as phyllite, argillite, and possibly schist. The character of these argillaceous rock fragments suggest that the source material included shales and siltstones that had undergone some low grade metamorphism.

The chert content is highly variable in lower Mannville strata, ranging from 0 to over 20 per cent. Some particles are medium to dark

grey in colour, and could be derived from material similar to the bedded chert that occurs in the outcrops of Mississippian strata in the Canadian Rocky Mountains. The presence of detrital chert in sediments indicates that the material was derived from pre-existing sedimentary rocks. In discussing this problem, Krumbein and Sloss (1956, p. 142) stated that "sediments represent 'second cycle' deposits in their chert content".

Metaquartzite fragments (composite particles, with each grain showing undulatory extinction) in the sandstones suggest that the source sediments suffered deformation. Individual quartz grains also support this suggestion, as up to 50 per cent, in several samples, show undulatory extinction in some degree.

Rutile, tourmaline and zircon, which are very resistant to abrasion, make up the bulk of the heavy accessory mineral assemblage of the lower Mannville group. Their subrounded to well rounded nature indicates they are several cycle grains, and further suggest that the lower Mannville group source material was sediments. Colour variation in the tourmaline particles suggests they may originally have been derived from terrain similar to the three basic types (granitic, pegmatitic or metamorphic) of source areas as described by Krynine (1946). Apatite, on the other hand, generally occurs as subangular anhedral particles and is less extensively abraded than its hardier associates. Therefore it is more likely to be a first cycle mineral. According to Johannsen (1928), and Rogers and Kerr (1942),

apatite occurs in pegmatites, lamprophyres, crystalline schists, metamorphic limestones or argillites. It is very likely that apatite found in this stratigraphic section is not of igneous origin, but rather from metamorphosed sedimentary rocks. No other certain first cycle igneous derivatives are present.

Source Area

The region from which lower Mannville sediments of the present area were derived is not known with any certainty. Detrital zone material is exceedingly heterogeneous, and does not appear to have been transported for any great distance, possibly only from pre-Cretaceous topographic highs to nearby lows. As shown on Figure 4 this zone is absent from the crest regions of this old land surface. Sandstones of the Ellerslie member are relatively "clean" and well rounded indicating a fairly long abrasion history. Petrographic studies by Mellon (1956) and G.D. Williams (personal communication) suggest that at least some of these sediments were derived from the Canadian Shield, but with a positive area in southeastern British Columbia a major contributor. For the overlying members, the western area is considered to be the dominant source. Glaister (1959, p. 631), working on a regional scope, stated "the source from which the sediments were derived probably lay in the vicinity of the present-day Selkirk Mountains".

Environment of Deposition

Sedimentary criteria, megafossils and fossil spores were utilized to give some suggestion of the type of environment into which lower Mannville sediments were transported.

The Detrital beds show no sorting and organic remains were not found in any of these samples examined.

Thin beds of coal in the Ellerslie member indicate that swamps existed locally when sediments of this unit were being laid down. The rounded nature of the quartz grains, paucity of chert particles and almost complete lack of argillaceous rock fragments in Ellerslie sandstones show it to be a mature sediment. Several well preserved plant leaves are preserved in the shales and siltstones of this unit. Therefore, in all likelihood the Ellerslie member was deposited under continental conditions of slow deposition in relatively shallow water.

Greater rate of erosion and deposition, caused the overlying sediments to be less mature. Chert and argillaceous rock fragments are common in the "Calcareous" and "Glauconitic" sandstone members. Coal beds in the "Calcareous" member indicate paludal conditions existed locally and plant remains suggest a continental or near continental site of deposition for these sediments.

As shown in Figure 4 the "Calcareous" member thins to the north in the study area, and is overlain by a relatively uniform layer of glauconitic sandstone. Glauconite is considered to be mainly neritic in origin (Cloud, 1955).

Some of the animals mentioned in the composite list (page 18) are similar to fresh-water types described and figured by Russell (1932), while others resemble marine fossils discussed by McLearn (1919, 1931, 1933).

Of those listed, some are similar to the following species described by Russell (1932), from near the top of the McMurray formation on the Hangingstone River northeastern Alberta:

Murraia naiadiformis Russell

Unio biornatus Russell

Goniobasis? multicarinata Russell

Lioplacodes bituminis Russell

Melania multorbis Russell

Viviparus murraiensis Russell

He (ibid. p. 7) regarded this fauna to be characteristic of the Lower Cretaceous and "predominantly composed of non-marine genera, and reckoning by individuals, is overwhelmingly of fresh-water habitat. However, there are several forms present suggesting brackish-water or even marine conditions." Further, he suggested that "the McMurray formation was developed under estuarine or near estuarine conditions."

McLearn (1919, 1931, 1933) described several species of molluscs from the Clearwater shale which overlies the McMurray formation. Several specimens in the "Calcareous" and "Glauconitic" sandstone members resemble four of the species he described. These are the following:

Brachidontes athabaskensis McLearn

Nucula athabaskensis McLearn

Onestia onestae (McLearn)

Thracia kissoumi McLearn

This fauna is considered distinctly marine by McLearn, but all of these genera are tolerant to a certain amount of brackishness. There is no observable difference in fauna from the "Calcareous" and "Glauconitic" sandstone members as fresh-water(?) and marine genera are present in each unit. Either each type became tolerant to the brackish water conditions that must have existed in that region or else the water became alternately fresh and saline, with varying stream discharge.

Characteristics of the lower Mannville sediments of the study area agree with criteria used by Krumbein, Dapples, and Sloss (1949) to identify a transitional (fluvial-lagoonal-littoral) type of environment.

In summary, the environment of deposition of the lower Mannville group in the thesis area shifted from continental at the base to marine shore-line conditions at the top. The presence of spores in the lower Mannville rocks indicate near shore conditions. If glauconite is mainly neritic in origin (Cloud, 1955), the "Glauconitic" sandstone member must indicate the southward transgression of a sea (the Clearwater Sea), drowning the river valleys in which the "Calcareous" deposits were laid down.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

This study was undertaken to correlate the rocks of the western margin of the lower Mannville group of the study area with the Mannville type section, and to determine the probable source area and environment of deposition of these rocks.

The samples studied were from cores of three wells (Imperial Christmas Creek #11-10, Imperial Cynthia #14-28, and Socony Seaboard Violet Grove #7-6) which are situated about 80 miles west of Edmonton in the upper Pembina River area. Lithologic criteria and electric well log profiles were employed to make the rock correlations and to give some indication of the provenance of the material. Fossils (megafossils and fossil spores) were used to determine the relative age of the rock-stratigraphic units and to facilitate the interpretation of the environment of deposition.

Lower Mannville strata discussed in this thesis are about 250 feet thick, and lie between the pre-Cretaceous unconformity and the top of the "Glauconitic" sandstone member.

The lower rocks of relatively "clean" quartz and "salt and pepper", very fine to medium-grained sandstones, siltstones and shales, contain several well preserved plant remains and a mixture of fresh-water(?) and marine faunas, the latter common near the top of this section. Stratigraphically above, the rocks are predominantly glau-

conitic, "salt and pepper", very fine to medium-grained sandstones with a few interbeds of shale and siltstone. The same faunal assemblages are found here as in the underlying unit. This intermingling of faunas indicates that the water was brackish and that the site of deposition was at or near the mouth of a river that flowed directly into the sea.

Lithologic criteria and organic remains indicate that the basal portion of the section was deposited under continental conditions, but grades upward into shallow marine deposits. The above characteristics readily satisfy the criteria used by Krumbein, Sloss, and Dapples (1949) to denote a transitional (fluvial-lagoonal-littoral) type of environment.

Organic remains in the lower Mannville sediments of the present area are believed to be Aptian and Albian in age and indicate that the interval studied has age affinities with the McMurray formation and a portion of the Clearwater formation of east-central Alberta. Lower Mannville rock-stratigraphic units of the study area are equivalent to the basal three members of type Mannville (i.e. Dina, Cummings, and Islay). A date of 75 million years from a sample of glauconite is considered to represent some late stage of diagensis. If the glauconite is up-dated, other components of lower Mannville strata may have been changed as well.

Thin sections and heavy accessory minerals from some of the sandstones suggest that the debris was derived from pre-existing sedimentary rocks that were metamorphosed in part.

It is the writer's opinion that sedimentary rocks lying to the west and southwest of the present-day Rocky Mountains in the vicinity of the Selkirk Mountains of southeastern British Columbia, may have supplied the major portion of the debris that now makes up the lower Mannville group in the study area. Rivers flowing to the northeast carried the material, depositing it in an estuary. Transgression of this sea (the Clearwater Sea) southward in Albian time laid shore-line deposits over continental sediments.

However, the configurations of these Albian rivers are not known with any certainty and the nature of the land mass in the vicinity of the Selkirk Mountains is one of conjecture. Quite possibly this positive area deflected some rivers northward that flowed from a region farther to the south or southeast. In such case only debris derived from the fringe area of the Selkirk land mass would find its way to central Alberta.

SELECTED BIBLIOGRAPHY

Andrichuk, J.M. (1949): Stratigraphy of the area including Majeau Lake No. 1 well, Edmonton area; M.Sc. thesis, University of Alberta, Edmonton.

Badgley, P.C. (1952): Notes on the subsurface stratigraphy and oil and gas geology of the Lower Cretaceous series in central Alberta; Geol. Surv. Can., Paper 52-11.

Bastin, E.S. (1933): Relations of cherts to stylolites at Carthage, Missouri; Jour. Geol., vol. 41, pp. 371-381.

Bell, W.A. (1956): Lower Cretaceous floras of Western Canada; Geol. Surv. Can., Memoir 285.

Brown, W.W.M. (1959): The origin of stylolites in the light of a petrofabric study; Jour. Sed. Pet., vol. 29, pp. 254-259.

Cloud, P.E., Jr. (1955): Physical limits of glauconite formation; Bull. Am. Assoc. Pet. Geol., vol. 39, pp. 484-492.

Conybeare, C.E.B. (1949): Stylolites in Pre-Cambrian quartzite; Jour. Geol., vol. 57, pp. 83-85.

_____ (1950): Microstylolites in Pre-Cambrian quartzite: a reply; Jour. Geol. vol. 58, pp. 652-654.

Dowling, D.B. (1915): The Crectaceous Sea in Alberta; Trans. Roy. Soc. Can., Ser. 3, sec. IV, vol. 9, pp. 27-42.

Duffell, S. (1959): Whitesail Lake Map-Area, British Columbia; Geol. Surv. Can., Memoir 299.

Dunnington, H.V. (1954): Stylolite development post-dates rock induration; Jour. Sed. Pet., vol. 24, pp. 27-49.

Gilbert, C.M. (1949): Cementation of some California Tertiary reservoir sands; Jour. Geol., vol. 57, pp. 1-17.

Giles, A.W. (1932): Textural features of the Ordovician sandstones of Arkansas; Jour. Geol., vol. 40, pp. 104-109.

Glaister, R.P. (1959): Lower Cretaceous of southern Alberta and adjoining areas; Bull. Am. Assoc. Pet. Geol., vol. 43, pp. 590-640.

Golding, H.H. (1959): Variation in physical constitution of quarried sandstones from Gosford and Sydney, N.S.W.; Jour. Proc. Roy. Soc. New South Wales, vol. 93, pp. 47-60.

Goldman, M.I. (1940): Stylolites; Jour. Sed. Pet., vol. 10, pp. 146-147.

Harker, A. (1939): Metamorphism; Methuen & Co. Ltd., London, pp. 143-145.

Hayes, J.R. and Klugman, M.A. (1959): Feldspar staining methods; Jour. Sed. Pet., vol. 29, pp. 227-232.

Heald, M.T. (1955): Stylolites in sandstones; Jour. Geol., vol. 63, pp. 101-114.

_____ (1956): Cementation of Simpson and St. Peter sandstones in parts of Oklahoma, Arkansas, and Missouri; Jour. Geol., vol. 64, pp. 16-30.

_____ (1959): Significance of stylolites in permeable sandstones; Jour. Sed. Pet., vol. 29, pp. 251-253.

Hunt, C.W. (1950): Preliminary report on Whitemud oil field, Alberta, Canada; Bull. Am. Assoc. Pet. Geol., vol. 34, pp. 1795-1801.

Johannsen, A. (1928): Essentials for the microscopical determination of rock-forming minerals and rocks; The University of Chicago Press, Chicago, Illinois.

Kidd, S.J. (1948): Lithology at Beaverhills Lake No. 2 well, with special emphasis on the insoluble residues in the Palaeozoic strata; M.Sc. thesis, University of Alberta, Edmonton.

Krumbein, W.C. and Garrels, R.M. (1952): Origin and classification of chemical sediments in terms of pH and oxidation-reduction potentials; Jour. Geol., vol. 60, pp. 1-33.

_____ and Pettijohn, F.J. (1938): Manual of sedimentary petrography; Appleton-Century-Crofts, Inc., New York.

_____ and Sloss, L.L. (1956): Stratigraphy and sedimentation; W.H. Freeman and Company, San Francisco, California.

_____ , Sloss, L.L., and Dapples, E.C. (1949): Sedimentary tectonics and sedimentary environments; Bull. Am. Assoc. Pet. Geol., vol. 33, pp. 1859-1891.

Krynine, P.B. (1946): The tourmaline group in sediments; Jour. Geol., vol. 54, pp. 65-87.

Layer, D.B., et al. (1949): Leduc oil field Alberta, a Devonian coral-reef discovery; Bull. Am. Assoc. Pet. Geol., vol. 33, pp. 572-602.

Loranger, D.M. (1951): Useful Blairmore microfossil zone in central and southern Alberta, Canada; Bull. Am. Assoc. Pet. Geol., vol. 35, pp. 2348-2367.

McLearn, F.H. (1917): Athabasca river section; Geol. Surv. Can., Sum. Rept. 1916, pp. 145-151.

_____ (1919): New species of Pelecypods from the Cretaceous of northern Alberta; Geol. Surv. Can., Mus. Bull. No. 29, pp. 9-12.

_____ (1931): The Gastroplites and other Lower Cretaceous faunas of the northern Great Plains; Trans. Roy. Soc. Can., Ser. 3, sec. IV, vol. 25, pp. 1-7.

_____ (1932): Problems of the Lower Cretaceous of the Canadian interior; Trans. Roy. Soc. Can., Ser. 3, sec. IV, vol. 26, pp. 157-175.

_____ (1933): Pelecypods of the Lower Cretaceous Clearwater formation, northern Alberta; Trans. Roy. Soc. Can., Ser. 3, sec. IV, vol. 27, pp. 139-156.

_____ (1944): Revision of the palaeogeography of the Lower Cretaceous of the western interior of Canada; Geol. Surv. Can., Paper 44-32.

_____ (1945): Revision of the Lower Cretaceous of the western interior of Canada; Geol. Surv. Can., Paper 44-17, 2nd ed.

Mellon, G.B. (1955): Age and origin of the McMurray formation; M.Sc. thesis, University of Alberta, Edmonton.

_____ (1956): Heavy minerals of the McMurray formation; Research Council Alta., Rept. No. 72, pt. II, pp. 30-38.

_____ (1959): Lower Cretaceous strata of the Cadomin area; Edmonton Geol. Soc., 1959 Field Trip Guide Book, pp. 9-12.

_____ and Wall, J.H. (1956): Foraminifera of the upper McMurray and basal Clearwater formations; Research Council Alta., Rept. No. 72, pt. I, pp. 5-29.

Nauss, A.W. (1945): Cretaceous stratigraphy of Vermilion area, Alberta, Canada; Bull. Am. Assoc. Pet. Geol., vol. 29, pp. 1605-1629.

Pettijohn, F.J. (1957): Sedimentary rocks; Harper and Brothers, New York.

Pocock, S.A.J. (1959): Comparison of the Canadian and European Jurassic-Cretaceous boundaries; Preliminary manuscript of paper read before Pittsburgh meeting of Geol. Soc. Am., Nov. 1959; listed in Program of Geol. Soc. Am., Annual Meeting, 1959, Pittsburgh, p. 22.

Price, P.H. (1934): Stylolites in sandstone; Jour. Geol., vol. 42, pp. 188-192.

Rogers, A.F. and Kerr, P.F. (1942): Optical mineralogy; McGraw-Hill Book Company, Inc., New York.

Russell, L.S. (1932): Mollusca from the McMurray formation of northern Alberta; Trans. Roy. Soc. Can., Ser. 3, sec. IV, vol. 26, pp. 1-7.

Schuchert, C. (1923): Sites and nature of the North American geosynclines; Bull. Geol. Soc. Am., vol. 34, pp. 151-230.

Shaub, B.M. (1939): The origin of stylolites; Jour. Sed. Pet., vol. 9, pp. 47-61.

_____ (1949): Do stylolites develop before or after the hardening of the enclosing rock?; Jour. Sed. Pet., vol. 19, pp. 26-36.

_____ (1959): Microstylolites in Pre-Cambrian quartzite: a discussion; Jour. Geol., vol. 58, pp. 650-652.

Sloss, L.L. and Feray, D.E. (1948): Microstylolites in sandstones; Jour. Sed. Pet., vol. 18, pp. 3-13.

Stockdale, P.B. (1922): Stylolites: their nature and origin; Indiana Univ. Studies, vol. 9, pp. 1-97.

_____ (1926): The stratigraphic significance of solution in rocks; Jour. Geol., vol. 34, pp. 399-414.

_____ (1936): Rare stylolites; Am. Jour. Sci., vol. 32, pp. 129-133.

_____ (1943): Stylolites: primary or secondary?; Jour. Sed. Pet., vol. 13, pp. 3-12.

_____ (1945): Stylolites with films of coal; Jour. Geol., vol. 53, pp. 133-136.

Taylor, J.M. (1950): Pore-space reduction in sandstones; Bull. Am. Assoc. Pet. Geol., vol. 34, pp. 701-716.

Thomson, A. (1959): Pressure solution and porosity; Soc. Econ. Paleont. & Mineral., Special Publication, No. 7, pp. 92-110.

Travis, R.B. (1955): Classification of rocks; Quart. Colorado School of Mines, vol. 50, number 1.

Wickenden, R.T.D. (1948): The Lower Cretaceous of the Lloydminister oil and gas area; Geol. Surv. Can., Paper 48-21.

_____ (1949): Some Cretaceous sections along Athabasca River; Geol. Surv. Can., Paper 49-15.

_____ (1951): Some Lower Cretaceous sections on Peace River below the mouth of Smoky River, Alberta; Geol. Surv. Can., Paper 51-16.

Williams, G.D. (1960): Lower Mannville group, central Alberta; Ph.D. thesis, to be submitted, University of Alberta, Edmonton.

Williams, H., Turner, F.J., and Gilbert, C.M. (1955): Petrography; W.H. Freeman and Company, San Francisco.

Willson, J.N. (1947): The stratigraphy of the Lloydminister and adjacent areas; M.Sc. thesis, University of Alberta, Edmonton.

Workman, L.E. (1958): The Blairmore group in the subsurface of Alberta; Guidebook, Alta. Soc. Pet. Geol., Ninth Annual Field Conference, pp. 122-129.

_____ et al. (1954): Lower Cretaceous of the Peace River region; Am. Assoc. Pet. Geol., Rutherford Memorial Volume, pp. 268-278.

Yen, Teng-Chien (1949): Review of the Lower Cretaceous fresh-water molluscan faunas of North America; Jour. Paleont., vol. 23, pp. 465-470.

_____ (1951): Fresh-water mollusks of Cretaceous age from Montana and Wyoming; U.S. Geol. Surv., Prof. Paper 233-A.

APPENDICES

&

PLATES

APPENDIX A

CORE DESCRIPTIONS

Imperial Christmas Creek #11-10
Lsd. 11, Sec. 10, Twp. 62, Rge. 10 W5M
K.B.: 2817'

Described from top of the interval downward:

Core #5 - 4835' to 4855' - Recovered 20'

5' 1" SILTSTONE, dark to medium grey, faintly mottled, pyritic, very slightly carbonaceous, irregularly bedded with shale partings common along bedding planes. The shale is better developed towards the base and grades into the underlying unit. Several 1" pyritized bands occur in the lower half of this interval.

11' 2" SHALE, dark grey, pyritic, slightly carbonaceous, micro-micaceous (?), fairly uniform paper-thin bedding, a few lenses and bands of lighter coloured material. The basal 2' is slightly more indurated.

1' 4" SANDSTONE, very fine-grained, "salt and pepper", light grey, pyritic, sparsely fossiliferous (pyritized pelecypods and plant remains), moderate to poor sorting, sub-angular, moderately well washed, fairly well cemented, tight. Conglomeratic between 8" and 10" from the top with the top capped by a 1/2" band of very pyritic shale. The base contains clay nodules, 1 1/2" to 2" in diameter. Sporadically arranged throughout the unit, are irregular laminations of black shale. (See Plate 1, Figure 1).

2' 5" SHALE and SILTSTONE in 1/4" to 1" slightly lensing interbeds.

Shale, black, slightly calcareous, fissile.
Siltstone, medium grey, slightly calcareous.
Irregular 1" nodules of highly pyritized siltstone are common, fossiliferous (plant remains and small pelecypods).

Core #6 - 4855' to 4885' - Recovered 30'

4' 6" SANDSTONE, very fine-grained, "salt and pepper", medium grey, argillaceous, calcareous, carbonaceous, sideritic (?), poorly sorted, subangular, poorly to moderately well washed, well cemented, tight, finely and very irregularly mottled and laminated with shale dark to medium grey, micromicaceous, carbonaceous, silty (?). A 1" band of this shale occurs at 9" from the top and another at 1' 3" from the top, otherwise it is present only in the fine laminations, becoming more common towards the base.

4' 0" SHALE, dark grey, pyritic, micromicaceous, very slightly calcareous, fissile. Irregular interbeds of sandstone, very fine-grained, "salt and pepper", medium brown grey, as above. Near the top these sandstone bands are commonly 1/4" - 1/2" thick, interbedded with 1/2" - 1" units of the shale. Towards the base these two lithologies become more evenly distributed and grade into the underlying unit. Patchy heavy oil staining is common in the sandstone.

0' 9" SANDSTONE and SHALE interbedded in 1/2" - 1" intervals.
Sandstone, fine to medium-grained, "salt and pepper", medium to light grey, calcareous, sideritic, slightly argillaceous, moderately well sorted, subangular, poorly to moderately well washed, fairly well cemented, tight.
Shale, dark grey, carbonaceous, micromicaceous, very slightly calcareous.

4' 9" SANDSTONE, very fine-grained, argillaceous, medium grey mottled with black, calcareous, carbonaceous, pyritic, silty, fossiliferous (1/2" diameter pelecypods). The sandstone is poorly sorted, subangular, poorly washed, moderately well cemented with hydrocarbon (?) impregnated material, tight. This unit becomes less mottled and more regularly banded with black shale towards the base.

2' 7" SANDSTONE, as above mottling is less pronounced, moderately fossiliferous. Possible bituminous material in pinpoint vuggy and tiny fracture porosity. The mottling is due to shale, black, micromicaceous, slightly sideritic (?) in places, fissile.

0' 6" COQUINA, light grey with white and light brown mottling, pelecypods and gastropods, shows a slight stratification.

1' 4" SANDSTONE, very fine-grained, quartz, slightly "salt and pepper", light grey, calcareous, fossiliferous (fragments of pelecypods ?), moderately well sorted, subrounded, fairly well washed, well cemented with calcareous material, tight.

2' 2" SANDSTONE, as above, light grey, irregularly and sporadically mottled with black shale.

4' 9" SANDSTONE, very fine-grained, ranging down to silt-size, slightly "salt and pepper", argillaceous, medium grey, slightly brownish at top progressively losing this tint towards base, irregularly mottled and streaked with dark coloured material, slightly calcareous, slightly glauconitic (?), poor to moderate sorting, subangular, poor to fair washing, well cemented, tight. Some rare partings and streaks of shale, black micromicaceous, fissile, non-calcareous, has a slight oily appearance. (See Plate 1, Figure 2).

4' 8" SANDSTONE and SHALE irregularly interbedded.

Sandstone, very fine-grained ranging down to silt-size, medium grey with a slight brownish tint, calcareous, carbonaceous, glauconitic (?), micromicaceous, poorly sorted, subangular, poorly washed to moderately well washed, tight.

Shale, black, fissile, micromicaceous, non-calcareous, faint oily appearance.

The sandstone dominates at the top grading to predominantly shale near the middle of the unit, then returning to a composition having approximately even amounts of sandstone and shale for the remainder of the interval.

Core #7 - 4885' to 4905' - Recovered 20'

5' 9" SHALE, dark grey, micromicaceous, pyritic, fossiliferous (plant remains ?), silty. The top 1' carries tiny lenses and bands of silty material which grades out downward. Top 3" contains three 1/2" bands of pyritized material. This unit is thin bedded, and fairly well indurated.

1' 4" SILTSTONE, medium grey, very pyritic, argillaceous, micromicaceous, hard, massively bedded. The basal 3" contains approximately 25% pyrite.

4' 10" SHALE, dark grey micromicaceous, carbonaceous, pyritic, fossiliferous (plant remains), very slightly calcareous, fissile.

8' 1" SANDSTONE, very fine to fine-grained with rare streaks of medium-sand-size, "salt and pepper", medium to light grey, pyritic, carbonaceous, slightly calcareous in places, poorly sorted, angular to subangular, fairly well washed, moderately well cemented, tight. The coarser phases contain some particles that may be altered feldspar. The larger portion of this coarse phase appears in the top 1' 6". Irregular laminations and bands occur sporadically due to shale and carbonaceous material (fossil wood). Some 1/8" bands of pyritized material appear about 4' from the top. 1 1/2' to 3 1/2' from the base the colour is slightly darker due to an increase in the percentage of shale. (See Plate 1, Figure 3).

Core #8 - 4905' to 4945' - Recovered 40'

2' 2" SHALE, black to dark grey, very pyritic in upper 7" then less common to base, slightly micromicaceous, non-calcareous, very thinly bedded. The basal 5" is mottled with medium grey shale with tiny lenses of a silty phase.

1' 0" COAL, with a few 1/2" - 1" patches of pyrite-cemented kaolinitic material.

6' 8" SANDSTONE, very fine-grained grading to silt-size, quartz, light grey to buff, slightly calcareous, well sorted, subrounded, well washed, fairly well consolidated, poor to fair cementing, poor intergranular porosity. Rare laminae of shaly material, mainly massive bedding with some thin bedding shown by fine shale partings, which is most prevalent in the upper 2' of the unit. In the top 1" the sand grains are cemented with pyrite, but this abruptly grades out downward. 1" to 6" from the top several vertical worm burrows are present. (See Plate 1, Figure 4; Plate 4, Figures 1 and 2).

1' 4" SANDSTONE, as above, irregularly mottled with black shale. Medium-sand-size particles of well rounded quartz occur in the lower half of this unit.

1' 4" SILTSTONE, light brown grey, slightly calcareous, carbonaceous (?), thinly bedded showing some simple cross-beds which commonly are finely laminated with black shale, faint petroliferous odor.

10' 6"	SILTSTONE, light brown grey to medium grey, non-calcareous, slightly pyritic in lower half of unit, irregularly interbedded with shale, which is present in the top portion of the unit as fine laminations, and partings becoming more common to base, thus imparting a dark to medium grey colour. 1" bands of pyrite cemented siltstone occur at 1", 5", 11" and 5' 5" from the base. Lenses of medium-grained sandstone are present in the lower 2' 6" of this interval. The bedding ranges from finely laminated to thin, very irregular, and lensing.
0' 3"	SHALE, black carbonaceous, fossiliferous (plant remains).
0' 3"	COAL
0' 9"	SHALE, dark grey, carbonaceous, fossiliferous (plant remains, and fossil wood), thin bedded.
11' 2"	SILTSTONE, light grey, with slight brownish tint occasionally, especially in lower 2', pyritic, carbonaceous, rarely micromicaceous, sporadic 1/2" to 2" interbeds of dark grey shale which grade into the siltstone, also irregularly laminated with black shale, mainly thin bedded. The shale is common between 1' and 3' above base. The basal 6" contains numerous particles of fine to medium-grained quartz sand.
1' 9"	SANDSTONE, fine-grained, rarely medium-grained, "salt and pepper", light grey mottled with dark grey, glauconitic, pyritic especially at the base, slightly calcareous, poorly sorted, subangular, moderately well washed, fairly well cemented, tight. Some oil staining is present in the coarser phases. Very irregularly laminated and lensed.
1' 10"	SILTSTONE, medium grey, calcareous, pyritic disseminated and 1/2" - 2" irregular nodules, slightly mottled with dark grey shale partings, irregularly laminated and thin bedded. Tiny slickensides occur at the base of this unit.
0' 8"	SHALE, dark grey, silty, calcareous, micromicaceous with irregular 2" nodules of pyritic material. The shale is thinly interbedded with silty phases.
1' 4"	SANDSTONE, fine to medium-grained, finest towards base, light grey faintly mottled brownish, calcareous, pyritic, slightly glauconitic, slightly carbonaceous, cherty (?), poorly sorted, subangular, moderately well washed, fairly well cemented, poor intergranular porosity.

Core #9 - 4945' to 4965' - Recovered 20'

1' 7"	SANDSTONE, fine-grained, "salt and pepper", light grey with some dark grey mottling due to irregular partings of shale, pyritic, glauconitic, slightly calcareous, moderately well sorted, subrounded, fairly well washed, moderately well cemented and consolidated, intensely mottled towards base.
0' 7"	SHALE, dark grey, silty, micromicaceous, pyritic, fossiliferous (pelecypod shells, and plant remains), slight oil staining in places, very thin bedded. Some of the fossils are pyritized.
3' 7"	SANDSTONE, very fine to fine-grained, "salt and pepper", light to medium grey, calcareous, pyritic, carbonaceous, slightly argillaceous, poorly sorted, subangular, poorly washed, moderately well cemented, tight, massively bedded mainly, with some thin to medium bedding due to a higher percentage of argillaceous material. The top 9' is slightly coarser and contains a fractured pyritized quartz pebble approximately 1/2" across.
3' 0"	SHALE, dark grey, pyritic, carbonaceous, paper-thin bedding, becomes silty near the base, also contains sporadic medium-sand-size quartz particles. The basal 10" contains numerous well developed slickensides.
0' 2"	COAL
2' 1"	SILTSTONE, argillaceous, light grey, sandy, carbonaceous, shale commonly occurs along the bedding planes of this thinly bedded unit. Top 4" is dark grey and grades up into the coal and the basal 2" is also dark grey in colour, grading into the underlying coal unit. This basal 2" contains numerous small shale and sandstone lenses.
0' 4"	COAL
3' 7"	CONGLOMERATE, coarse-pebble-size, medium to light grey, fairly well rounded, poor sphericity, bentonitic shale matrix. The sandstone in the phenoclasts is fine-grained, "salt and pepper", moderately well sorted, subangular, fairly well washed, fair to poor cement, good intergranular porosity. (See Plate 3, Figure 2; Plate 4, Figures 3 and 4).
3' 7"	SILTSTONE, dark to medium grey, mottled light grey in parts, sandy, argillaceous, carbonaceous, conglomeratic, mainly in the top 1', very thin bedded and very irregular in places.

1' 4" SILTSTONE and SHALE, dark to medium grey, well developed slickensides are common in the shale, both are slightly carbonaceous. 8" from the top, bleeding a small amount of oil.

Imperial Cynthia #14-28
Lsd. 14, Sec. 28, Twp. 52, Rge. 11 W5M
K.B.: 2940'

Described from the top of the interval downward:

Core #26 - 6616' to 6650' - Recovered 34'

12' 2" SANDSTONE, very fine-grained, "salt and pepper", medium to light grey, glauconitic, pyritic, carbonaceous, non-calcareous, moderate to poorly sorted, subangular, fairly well washed, moderately well cemented, and consolidated, tight, thin bedded with irregular laminae of black shale common, which becomes more prevalent down section thus imparting a darker colour to the core. Mottling is common. (See Plate 4, Figure 5).

1' 4" SANDSTONE, and SHALE, in 1" to 1 1/2" interbeds.
Shale, dark grey, micromicaceous (?), rarely finely carbonaceous, very slightly calcareous.
Sandstone, very fine-grained to silt-size, medium grey, pyritic, calcareous.
5" from the top is a 2" band of sandstone with coarse-sand-size vuggy porosity. This band is more calcareous than the other sandstone interbeds. Two less distinctive vuggy lenses occur above this 2" band.

0' 9" SILTSTONE, "salt and pepper", medium to light grey, calcareous, pyritic, massively bedded.

2' 10" SILTSTONE, and SHALE in 1" to 3" irregular interbeds and lenses.
Siltstone, medium grey, pyritic and chalcopyritic, carbonaceous, slightly calcareous. This lithology is more common in the lower half of the unit.
Shale, dark grey, calcareous, fairly well indurated. Top 6" is mottled as the two components are very irregularly bedded and lensed. 1' from the top a slickenside occurs along a shale parting in some siltstone. The lower 1' is mainly siltstone with irregular laminations of dark grey shale. Lower 9" fossiliferous (pelecypods, which are commonly pyritized). (See Plate 3, Figure 4).

16' 11" SHALE, dark grey, micromicaceous, fossiliferous, slightly pyritic. The top 2' is mainly barren of fossils then downward becomes very fossiliferous with a 1" band of coquina 4' 4" from the top. Possible fish tooth 1' 9" from the top, thin bedded, becoming slightly irregular towards base where it becomes faintly mottled medium grey due to a siltiness which lenses occasionally.

Core #27 - 6699' to 6725' - Recovered 26'

10' 3" SHALE, black to dark grey, pyritic, sporadically slightly glauconitic, fissile (?), thin bedded, fairly well indurated. The top 1' contains several 1/2" lenses of medium grey fine-grained glauconitic sandstone. Between 2' and 3' from the base a similar sandstone is present. Sporadically located throughout the interval are tiny lenses, pockets, or isolated grains of quartz (fine-sand-size).

3' 1" SANDSTONE, very fine to fine-grained, argillaceous, "salt and pepper", dark to medium grey, glauconitic, slightly pyritic, poorly sorted, subangular to subrounded, poorly washed, moderately well cemented and consolidated, tight. Irregularly thin bedded and mottled due to lensing and intercalating of the sandstone and black shale. The shale appears as laminae, and partings commonly. The pyrite often occurs as a cement for the sand particles.

0' 9" SANDSTONE, fine-grained, "salt and pepper", medium to light brown grey, pyritic, sideritic, shaly in streaks, and pockets, moderately well sorted, angular to subangular, poorly washed, well cemented, tight, massively bedded. Near the middle of the unit occurs an irregular 4" band of light brown shale.

2' 10" SANDSTONE, very fine-grained, quartz, light grey, mottled with medium grey, less commonly, black, limonitic in tiny patches scattered throughout, moderately well sorted, subangular, fairly well washed, moderately well cemented, and consolidated, tight. Bedding is very irregular with laminations of black shale common, mainly massive. This unit grades into the underlying interval.

9' 1" SANDSTONE, and SHALE in irregular very thin interbeds.
Sandstone, very fine-grained, quartz, light grey, very slightly calcareous, moderately well sorted, subangular, fairly well washed, moderate to poor cementing, fairly well consolidated, tight.

Shale, black to dark grey, slightly pyritic, and slightly bentonitic.

1' to 3' from the top the sequence is mainly shale, while elsewhere it forms a matrix of laminae, partings, and alternate beds, as the sandstone occurs as irregular 1/2" nodules or pockets, and irregular 1/2" - 1" bands, and lenses.

Core #28 - 6725' to 6747' - Recovered 22'

1' 7" SHALE and SANDSTONE, as above.

1' 4" SANDSTONE, very fine-grained, quartz, medium to light grey, slightly argillaceous, calcareous, carbonaceous, and limonitic (?), fairly well sorted, subangular, moderately well washed, well cemented, tight. Faintly mottled by black shale laminae and lighter, non-argillaceous phases of the same sandstone. This interval grades from the one above and into the one below.

14' 0" SANDSTONE, and SHALE, interbedded.

Sandstone, very fine-grained, quartz, medium to light grey, slightly argillaceous, very rarely calcareous, fairly well sorted, subangular, moderately well washed, fairly well cemented, tight.

Shale, black to dark grey, micromicaceous, fissile, slightly bentonitic, fairly well indurated.

The top 2' are light grey in colour as is the interval from 2' to 4' above the base. The basal 1' 6' is predominantly black shale. The sandstone is the main constituent occurring as 1/4" - 1" nodules, and "pockets", and as bands, and lenses 1/8' to 2" thick. Throughout, the shale is present as laminae, partings bands up to 1" thick.

5' 1" SANDSTONE, very fine-grained, quartz, light grey, slightly calcareous, rarely pyritic, rarely micromicaceous, well sorted, subangular to subrounded, well washed, moderately well cemented, well consolidated, good intergranular porosity, thin bedded. The top 1' is slightly darker in colour (medium grey) and contains structure 3" wide and vertical, resembling a shale dike. (See Plate 4, Figure 6).

Core #29 - 6747' to 6780 - Recovered 33'

8' 9" SANDSTONE, very fine-grained, quartz, light grey, slightly calcareous, more common towards base, rarely pyritic (fine and disseminated), rarely micromicaceous, fairly well sorted, subangular to subrounded, well washed, slightly less near base, moderately well cemented, well consolidated, good intergranular porosity, thin bedded. Buff shaly material tends to become more common in the lower half of this unit. A 1/2" irregular band of dark grey shale cuts the sequence 3' 10" from the top.

8' 4" SANDSTONE, very fine-grained, quartz, slightly "salt and pepper", medium to light grey commonly with a slightly brown to buff tint, faintly mottled due to irregular dark grey shale laminations and partings throughout, rarely micromicaceous, fairly well sorted, subangular to subrounded, moderately well washed, well cemented and consolidated, fair to poor porosity, faintly thin bedded.

4' 4" SANDSTONE, very fine-grained, argillaceous, medium grey, faintly mottled with dark grey shale and light grey sandstone, micromicaceous, rarely pyritic (fine and disseminated), moderately well sorted, subangular, poorly washed, well cemented, and indurated, tight, faintly visible irregular thin beds. The sandstone occurs as tiny (1/8" to 1/4") patches and "pockets" with minute lenses, and bands (1/8") common. Shale acts as a matrix occurring as laminae, and bands. This unit is approximately 75% sandstone and grades into the underlying interval.

7' 4" SANDSTONE, very fine to fine-grained, quartz, medium to light grey with brownish tint common, slightly calcareous, rarely pyritic, and very rarely glauconitic, moderately well sorted, subangular, moderate to well washed, fairly well cemented and consolidated, poor porosity to tight. Mainly massive with a faint sporadic mottling due to dark grey shale irregularly laminated which are abundant between 1' and 2' above the base and range in size to 1/4" to 1/2" irregular bands. (See Plate 4, Figure 7).

4' 3" SANDSTONE, fine-grained, "salt and pepper", calcareous, light grey, micromicaceous, rarely glauconitic, poor to moderate sorting, angular, fairly well washed, well cemented and consolidated, tight, massive to thinly bedded with rare to common irregular dark grey shale laminations.

Socony Seaboard Violet Grove #7-6
Lsd. 6, Sec. 7, Twp. 48, Rge. 7, W5M
K.B.: 2896'

Note: This core was cut having a 2 1/2" diameter, and was boxed with three 2 1/2' lengths in each core box. Unfortunately dividers were not used to separate the three lengths, therefore in the case of badly broken intervals a mixing of the different lengths was quite evident. To offset this, considerable use was made of the Mobil Oil core descriptions concerning the unit, or units in question, as to thickness and lithology.

Described from the top of the interval downward:

Core #30 - 6530' to 6566' - Recovered 36'

14' 6" SHALE, medium grey, silty, carbonaceous, pyritic (irregular 1/2" to 1" nodules, occasional "fern-like" structures), slightly calcareous in places, rarely fossiliferous (plant remains), thin bedded, hard. Interbedded and occasionally intermixed with the shale are bands of: Sandstone, (some up to 2" thick), very fine-grained, "salt and pepper", pyritic, carbonaceous, micromicaceous, moderately well sorted, subangular, well washed, fair to poor cementing, but well consolidated, tight, thin bedded. The percentage of sandstone in this unit does not exceed 25%.

Considering these two phases, the bedding is generally regular with occasional cross and/or wavy bedding. The amount of pyrite increases towards the base. Sporadic 1" to 2" bands of ironstone are present throughout. 1' 3" from the top there is a well developed slickenside parallel the horizontal bedding.

1' 0" LIMESTONE, very finely-crystalline, medium to light grey, silty (ranging to calcareous siltstone in places), pyritic (fine and disseminated), carbonaceous with thin streaks and laminations of black shale, thin bedded, hard, occasional veinlets of white calcite.

14' 0" SHALE, black to dark grey, very pyritic (fine and disseminated, particles and crystals, irregular nodules up to 1/2" in diameter, and "finger-like" structures less common), very slightly fossiliferous (poorly preserved plant remains), rare occurrences of slickensides, very thin bedded, hard. Sporadic bands, and lenses of siltstone, and sandstone. Sandstone, fine-grained, glauconitic, pyritic. Both are tight. Percentage of sandstone, and siltstone is less than 10.

Bedding is thin, regular, with some simple cross, and wavy bedding.

6559' Top of Glauconite Sandstone

6' 6" SANDSTONE, fine to medium-grained, "salt and pepper", medium to light grey, glauconitic, pyritic, moderate sorting, sub-angular (occasionally subrounded), fair to poor washing, fairly well cemented, and consolidated, patchy poor porosity, otherwise tight. Commonly the intergranular spaces are filled with bitumen, bedding is mainly massive with occasional wavy laminations of dark grey shale.

Core #31 - 6566' to 6604' - Recovered 38'

19' 10" SANDSTONE, as above, slightly micromicaceous. The quartz grains becoming commonly cloudy, unlike the unit above. Becoming slightly calcareous and argillaceous towards base, bedding massive, with some thin bedding, sporadic throughout are irregular, and wavy dark grey shale partings, laminae, and lenses (up to 1/4"). (See Plate 4, Figure 8).

5' 4" SANDSTONE, silt-size to very fine-grained, medium grey, argillaceous, silty, pyritic, slightly glauconitic, very slightly calcareous, poorly sorted, subangular, poorly washed, well cemented, tight, thinly bedded, faintly irregularly laminated, and cross-bedded with black shale partings.

2' 2" SANDSTONE, very fine-grained, "salt and pepper", medium grey, slightly greenish in places, very glauconitic, pyritic, slightly calcareous, fairly well sorted, subangular to subrounded, poor to fair washing, well cemented, tight, thinly irregularly bedded, commonly laminated and streaked with dark grey shale which is micromicaceous and carbonaceous. Also streaked and lensed with highly glauconitic phases. In these lenses and streaks glauconite may make up to 50% of the components. For the whole unit glauconite may be 20% of the consitituents.

0' 8" SILTSTONE, medium to light grey, very glauconitic, sandy, shaly, pyritic, calcareous, thin bedded with irregular laminations and partings of black shale, also intercalations of high glauconitic phases.

3' 8" SANDSTONE and SHALE irregularly intermixed and lensed.
Sandstone, very fine to fine-grained, "salt and pepper", medium grey, very glauconitic, pyritic, very slightly calcareous, poorly sorted, subangular, poorly washed, well cemented, and consolidated, tight. (See Plate 2, Figure 3).

Shale, dark grey, micromicaceous, pyritic, glauconitic, fissile.

Bedding is thin and irregular with abundant laminations of black shale. The intermixing of dark and medium grey phases imparts a mottled effect to the rock. The dark colour predominates in the basal portion of this unit and grades down into the underlying interval.

6' 4" SHALE, dark grey, fossiliferous (gastropods, pelecypods, ostracods, and plant remains), pyritic (minute threads, and rare 1/2" irregular nodules), slightly calcareous, hard. Rarely occurring are 1/4" lenses of sandstone, as above. Between 4' and 5' above the base is a fossil bed of gastropods and pelecypods. The ostracods are confined to the basal 4'. Thin bedded, occasionally banded with 1/8" to 1/4" thick sandstone beds.

Core #32 - 6604' to 6646' - Recovered 41' 11"

0' 4" SHALE, black, very calcareous, pyritic, carbonaceous, fossiliferous (plant remains, and ostracods). Thinly interbedded, with siltstone, light grey, pyritic, shows some fine scale cross-beddings.

1' 6" LIMESTONE, very finely-crystalline, black, slickensides are common, hard, massive, veinlets of calcite are abundant.

12' 10" SHALE and SILTSTONE, intermixed, thinly interbedded and lensed (1/2" to 1").

Shale, dark grey, calcareous, micromicaceous, carbonaceous, fossiliferous (pelecypods up to 1" diameter, rarely ostracods), some slight oil staining on bedding planes.

Siltstone, medium grey, "salt and pepper", very calcareous, pyritic, glauconitic, carbonaceous.

The shale is most common in the top portion of this unit, mainly thin bedded. The core has a mottled appearance with irregular laminations and partings of shale outlining lenses of siltstone. Possibly accumulation of winnowing action producing "swirling" and cross-bedded structures.

11' 9" SHALE, black, calcareous, fossiliferous (pelecypods, commonly compressed parallel to bedding, and ostracods), pyritic (disseminated), micromicaceous, silty, hard, thin bedded, with silty bands common in the lower half of this unit. These silty bands are slightly lighter in colour giving the core a banded appearance. Near the base the

pelecypods are pyritized commonly. The basal 6" has several "pockets" of broken pelecypod shells, often partially pyritized.

2' 3" SHALE and SILTSTONE, intermixed, and intercalcated (50:50).

Shale, black, calcareous, fossiliferous (pelecypods), pyritic (disseminated), micromicaceous.

Siltstone, "salt and pepper", medium grey, calcareous, pyritic (minute nodules and streaks, replacing some organic material ?).

The bedding reflects evidence of turbulence with its mottled appearance. Both components are hard, and tight.

2' 0" SHALE, black fossiliferous (ostracods, less frequently pelecypods, and some fossil wood), calcareous, micromicaceous, slightly pyritic, rarely silty in 1/4" bands, hard, thin regular beds.

8' 0" SANDSTONE, fine to medium-grained, "salt and pepper" (the dark particles appear to be mainly chert), light grey to buff, slightly calcareous, slightly pyritic, poor to moderate sorting, angular to subangular, well washed, poorly cemented, well consolidated, fair to good intergranular porosity. Fine bitumen breaks are common, thinly bedded, faintly streaked and laminated with dark grey shale, showing irregular cross-beds as well as horizontal regular beds. (See Plate 2, Figure 2; Plate 4, Figures 9 and 10).

1' 6" SANDSTONE, medium to coarse-grained, "salt and pepper" (cherty ?), light grey, minutely mottled dark grey, very calcareous, slightly sideritic (?), well sorted, angular to subangular with the quartz particles commonly subrounded, well washed, well cemented (calcite ?), hard, and well indurated, tight, thin bedded, streaked, and mottled showing mainly regular beds, slightly tilted, and occasionally cross-bedded. Streaked with bitumen 1" and 4" from the top. (See Plate 2, Figure 1; Plate 4, Figures 11 and 12; Plate 5, Figures 6, 7, 8, 9, 11 and 12).

1' 9" SANDSTONE, silt-size to very fine-grained, "salt and pepper", dark to medium grey, very calcareous, very finely pyritic, carbonaceous, fossiliferous (fragments of pelecypod shells, rarely ostracods), argillaceous, moderately well sorted, subangular, poorly washed, fairly well washed in places, well cemented, hard, tight, irregularly thin bedded, mottled, indication of turbulence during deposition.

Core #33 - 6646' to 6668' - Recovered 22'

1' 6" SANDSTONE, very fine to fine-grained, argillaceous, medium grey, mottled, and streaked with light grey, calcareous, fossiliferous (broken pelecypods and ostracods), traces of fine pyrite, poorly sorted, angular to subangular, poorly washed, well cemented (calcite), and consolidated, tight, hard, thin bedded (regular, and irregular intermixed, indicating turbulence at time of deposition).

10' 6" SHALE, dark grey, very calcareous, ranging to a very argillaceous limestone in places, silty, pyritic (fine and disseminated, with fine stringers), micromicaceous, fossiliferous (pelecypods, some pyritized), well consolidated, very hard, thin bedded, irregular lenses and streaks of lighter coloured phases, also commonly laminated with black shale.

2' 0" SHALE, dark grey, pyritic (disseminated small crystals and "threads"), micromicaceous, slightly calcareous, slightly carbonaceous, slightly silty, fossiliferous (pelecypods, occasionally pyritized), well consolidated, hard, thin regular beds.

5' 0" SHALE, medium grey, fossiliferous (pelecypods and ostracods ?), micromicaceous, pyritic (fine "threads" and minute nodules), very slightly calcareous, rarely carbonaceous, well consolidated, and hard, bedding is mainly obscured, shows some thin cross-bedding, appears mainly irregular. Occasional streaks of sandstone, fine-grained, poorly sorted.

3' 0" SANDSTONE, very fine-grained, "salt and pepper", argillaceous, medium to light grey, calcareous, fossiliferous (pelecypods), slightly pyritic (finely disseminated), poorly sorted, angular to subangular, poorly to moderately well washed, well cemented, well consolidated, hard, tight, massive.

Core #34 - 6668' to 6690' - Recovered 21'

10' 0" SHALE, (grading to siltstone occasionally), medium grey, pyritic (fine and disseminated, and small stringers), carbonaceous, micromicaceous, very slightly calcareous, rarely fossiliferous (plant remains and pelecypods ?), possible slight oil stain in places, hard, tight, thin irregular beds, showing some cut-and-fill structure 3' from the tip. also other evidence of turbulent conditions of deposition. Commonly contains lenses, and streaks of sandstone, very fine-grained, "salt and pepper", light grey, non-calcareous.

This unit grades into the underlying interval.

11' 0" SILTSTONE, (grading to shale occasionally and rarely to sandstone, very fine-grained), dark to medium grey, mottled light grey, pyritic (fine disseminated crystals and nodules), carbonaceous, fossiliferous (plant remains), hard, well consolidated, tight, thin irregular beds, irregular lenses, and bands throughout. Black shale laminations are common.

Core #35 - 6690' to 6732' - Recovered 42'

7' 2" SHALE, silty, dark-medium grey, calcareous, micromicaceous, occasionally fossiliferous (plant remains and pelecypods) rarely pyritic (disseminated and irregular nodules, 1/4"), well consolidated, and hard. Becomes quite silty between 4" and 3' from the top. Massive, mainly with a few indications of fine irregular laminae of cross-bedding showing evidence of turbulence.

5' 3" SHALE, dark grey, carbonaceous, fossiliferous (plant remains, slightly pyritized), micromicaceous, slightly pyritic (very fine and disseminated).

Towards the base this unit becomes more pyritic, calcareous, silty, grading into a siltstone, hard, and tight throughout. Thin regular beds in the main, with some faint shows of cross-beds, and undulations, generally appears massively bedded.

4' 10" SILTSTONE, medium grey, commonly mottled, and banded with dark grey, carbonaceous, bituminous, fossiliferous (fairly well preserved plant remains), micromicaceous, pyritic near base, slightly calcareous, hard, tight, thin irregular beds, and bands with simple cross-beds, also laminations, and bands of black shale (up to 1/4" thick), especially between 2' to 3' from the top, grading to a sandstone at the base into the underlying unit.

4' 2" SANDSTONE, very fine to fine-grained, "salt and pepper", medium to light grey, fossiliferous (plant leaf remains very well preserved), calcareous, carbonaceous, bituminous, pyritic (fine and disseminated), slightly argillaceous, well sorted, angular to subangular, fairly well washed, well cemented, and consolidated, hard, tight, thin bedded, and banded with a dark grey colouration. Shows simple wavy, and cross-bedding. The bituminous material commonly lies along the wavy bedding planes. In the basal 2' occasionally occurring are 1/4" to 1/2" lenses, or "eyes" of bentonitic shale.

3' 7" SHALE, dark grey, fossiliferous (plant remains, often pyritized), pyritic (disseminated, irregular nodules to 1/2" diameter), carbonaceous, bituminous, micromicaceous, silty, hard, thin regular beds to massive. Becoming more silty in the basal 1' progressively grading into the underlying sandstone interval. This silty phase is slightly lighter in colour, and shows some signs of turbulence during deposition.

3' 10" SANDSTONE, very fine to fine-grained ranging to medium-grained between 1' and 1' 6" from the top, medium grey, fossiliferous (some well preserved plant remains), carbonaceous, argillaceous (in streaks), very slightly calcareous, rarely pyritic (fine and disseminated), moderately well sorted, subangular, rarely subrounded, poorly to moderately well washed, well cemented, and consolidated, tight, thin irregular wavy, and cross-beds, small irregular laminae, and streaks of black shale appear throughout this unit. The finer phase of this sandstone occurs in the basal portion.

1' 5" SHALE, black to dark grey, carbonaceous, bituminous, micromicaceous, pyritic (fine and disseminated in the main, with some clusters of fine particles, occasionally irregular 1/4" nodules), fossiliferous (plant remains fairly well preserved). The top 6" contains a high percentage of coal with several "eyes", nodules and lenses of fine-grained pyrite, commonly coated with yellow, and white powder as though products of disintegration, massively bedded, mainly with faint signs of fine laminae and thin beds.

12' 8" SANDSTONE, very fine to fine-grained, "salt and pepper", medium grey, pyritic (fine and disseminated), bituminous, slightly calcareous (especially near the base), carbonaceous, argillaceous, rarely micromicaceous, fairly well sorted, angular to subangular, poor to fair washing, well cemented, hard, tight, thinly bedded and banded, commonly laminated with shaly or bituminous material. Cross, and wavy beds are common throughout with an apparent dip of up to 18° present especially between 5' and 10' from the top. The base is faintly mottled with evidence of turbulence during deposition. The unit is very fine-grained at the top, becomes fine-grained in the middle portions, then reverts to a very fine-grained texture at the base.

Core #36 - 6732' to 6752' - Recovered 20'

2' 2" SANDSTONE, very fine-grained, "salt and pepper", medium to light grey, calcareous, pyritic (fine and disseminated), slightly argillaceous, slightly sideritic, rare glauconitic, fairly well sorted, subangular, moderately well washed, well cemented, and consolidated, hard, tight, mainly massive, with faint thin beds, and laminations of black shale. 1/2" break of black shale 5" from the top.

5' 0" SILTSTONE, medium grey, micromicaceous, fossiliferous (bituminous plant remains, ostracods ?), pyritic (fine and disseminated, clusters, and small "threads"), well consolidated, hard, thin bedded, irregular laminations of dark grey shale are common. Small simple cross-beds, and lenses are prevalent throughout. Near the top of this unit a shaly phase is most prominent.

0' 1" ALUM (?), medium grey to white with yellow staining common. Seems to be a disintegration product that has come into being as the core lay in the boxes.

11' 9" SANDSTONE, very fine to fine-grained, medium grey, mottled with light grey, and streaked with dark grey, argillaceous, slightly calcareous in scattered places, rarely carbonaceous, poor to fair sorting, angular to subangular, moderately well washed, well washed in part, fairly well cemented, well consolidated, hard, poor intergranular porosity, thin irregular beds, partings, and laminations of black shale are common, mainly in the lower half of this unit as is wavy bedding and evidence of turbulence. Basal 5' becomes less argillaceous, but black shale breaks, and laminations are more common, and vivid. (See Plate 2, Figure 4).

1' 2" SANDSTONE, medium-grained, clean quartz, light grey, slight brownish tint occasionally, calcareous, cherty (few grains), argillaceous (few buff "kaolinite-like" grains scattered throughout), well sorted, subrounded, rarely rounded, fair to good washing, poorly cemented, fairly well consolidated, good intergranular porosity. Well developed simple cross-beds with carbonaceous, and bituminous streaks, and partings. (See Plate 5, Figure 1).

Core #37 - 6752' to 6758' - Recovered 6'

6' 0" SANDSTONE, medium-grained, clear quartz, light grey, argillaceous in streaks, numerous, bituminous breaks, occasional chert, and "kaolinite-like" grains, subangular to subrounded, good intergranular porosity, some intergranular bitumen in basal 6". Top 4' shows fairly good oil staining.

Core #38 - 6758' to 6773' - Recovered 15'

12' 3" SANDSTONE, fine to medium-grained, occasionally coarse-grained, light grey with slight brownish tint, often mottled dark grey in the lower half, fossiliferous (poorly preserved plant remains), carbonaceous in streaks, occasional chert grains, common buff argillaceous ("kaolinite-like") grains scattered throughout, very slightly calcareous in sporadic places, well sorted, subrounded, occasionally rounded, fair to well washed, poorly cemented, well consolidated, fair to good intergranular porosity. The thin bedding is only faintly visible in the upper part of this interval, generally regular, some slightly waving bedding due to dark grey streaks. Fine bituminous, carbonaceous, and occasional shale laminae throughout section. Basal half shows good simple cross-bedding and evidence of turbulence during deposition. (See Plate 5, Figure 2).

0' 6" SANDSTONE, coarse-grained, clean quartz, light grey, slightly brownish, calcareous, carbonaceous, bituminous, pyritic (fine and disseminated), with many well rounded, large chert grains, and "kaolinite-like" grains are common, giving the appearance of a micro-conglomerate. Bedding is thin and irregular. There is a definite irregular contact with the underlying shale.

2' 8" SHALE, black to dark grey, slightly lighter in colour near the top, micromicaceous, silty throughout (more common in top 1' 6"), carbonaceous, fossiliferous (poorly preserved plant remains), pyritic (clusters of fine particles), solitary 1/4" "pocket" of alum (?), well consolidated, hard. The thin regular bedding is mainly obscured.

Core #39 - 6774' to 6799' - Recovered 25'

9' 10" SHALE, dark grey, micromicaceous, fossiliferous (carbonaceous, and pyritized plant remains), slightly pyritic (fine, and disseminated, occasionally lenticular shaped bodies 1/16"). Becomes very micromicaceous, and silty in basal 6", bedding is thin but only faintly visible. Sharp irregular contact with the underlying sandstone, slight petroliferous odor.

2' 3" SANDSTONE, very fine to fine-grained, quartz, light grey to buff, slightly argillaceous (buff coloured particles), rarely fossiliferous (carbonized plant remains), fairly well sorted, subangular, moderately well washed, well cemented, and consolidated, hard, tight, slight trace of oil staining, and intergranular bitumen, occasional "pockets" (1/2") of clean quartz with fair to good porosity, massive.

0' 3" SHALE, dark grey, interbedded with sandstone, as above, thin bedded.

6' 6" SANDSTONE, very fine to fine-grained, quartz, rarely smoky, medium to light grey to buff, slightly argillaceous in part, traces of pyrite (fine, and disseminated), sporadically carbonaceous, fairly well sorted, subangular, fair to well washed, poorly cemented, but well consolidated, hard, poor intergranular porosity to tight, faintly oil stained. Bedding is thin, and irregular, dark grey shale, carbonaceous, and bituminous streaks, and breaks are common throughout, especially in the top 2' and basal 2'. Two 1/4" bands of shale occur between 1' 3" and 2" above the base. An apparent dip of 20° is evident at the base, but generally the bedding is horizontal, and irregular.

0' 2" COAL, with sandstone, as above, apparent dip of 20°.

5' 7" SANDSTONE, fine-grained, rarely medium-grained, quartz, mainly clear, rarely cloudy, carbonaceous, fossiliferous (carbonaceous plant remains), argillaceous, with abundant particles of buff coloured material, medium-sand-size (kaolinite ?), rarely cherty, moderately well sorted, subangular, occasionally subrounded, poor to fair washing, poorly cemented, fairly well consolidated, hard, poor intergranular porosity, patchy oil staining (poor to fair). Bedding is massive to thinly laminated with prominent bituminous streaks and breaks, intergranular bitumen is common. Horizontal irregular, and cross-beds between 2' and 3" from the top have an apparent dip to 20°. 4" from the top is a 1" break of dark grey shale. In the basal 3' the bitumen streaks and lenses range to 1/4" thick.

Core #40 - 6799' to 6807' - Recovered 8'

8' 0" SANDSTONE, fine to medium-grained, quartz, medium to light grey, darker towards the base, occasionally buff, fossiliferous (carbonaceous plant remains), carbonaceous, and bituminous streaks, and patches, abundant argillaceous material throughout, medium-sand-size particles, occasionally appear to be a matrix material (buff, kaolinitic ?), rarely cherty, fair to good sorting, subangular, rarely subrounded, moderately well washed, poorly cemented, but well consolidated, hard, poor to fair intergranular porosity, patchy oil staining, from slight to good. Thinly bedded, with an apparent dip of 10° to 15° common, finely laminated with dark grey shale, with streaks, lenses, and partings of coal abundant in the lower half of this unit, occasionally ranging up to 1/2" thick.

Core #41 - 6807' to 6826' - Recovered 19'

7' 10" SANDSTONE, fine-grained, becoming medium-grained in the basal 3', argillaceous, "salt and pepper", medium to light brown grey, extensively mottled and streaked with black coloured material, carbonaceous, bituminous, poorly sorted, subangular, occasionally subround, poor to fair washing, well cemented and consolidated, moderately hard, some patchy poor to fair porosity, mainly tight, especially in the central region of this interval, slight oil staining near the top. Diagonally thin bedded, irregular streaks, lenses, and laminations of bituminous material. These breaks are so common in the lower half that a darkening of the colour is imparted. Turbulence during deposition is evident. 1' 6" above base, are a few angular fragments of quartz and/or chert up to 1" in diameter. (See Plate 5, Figure 3).

0' 6" SHALE, dark grey, micromicaceous, bituminous, fossiliferous (carbonaceous, and bituminous plant remains), rarely pyritic (irregular 1/4" nodules), contains a well developed, highly polished slickenside.

1' 3" SANDSTONE, very fine-grained, as above, very carbonaceous, becoming argillaceous at base, some oil staining, mainly tight, shows thin irregular beds and evidence of turbulence. (See Plate 3, Figure 1).

0' 7" SHALE, as above, with well developed slickensides.

3' 5" SANDSTONE, very fine-grained, argillaceous, "salt and pepper", medium brown grey, carbonaceous, (minute particles and fragments), fairly well sorted, subangular, poor to fair washing, fairly well cemented, and consolidated, hard, tight, rare poor porosity, massive, mainly with faint thin wavy beds, due to darker coloured material. Top 1' contains a small poorly developed slickenside.

2' 8" SANDSTONE, fine-grained, becoming very fine-grained towards the base, quartz, faintly "salt and pepper", slightly carbonaceous (more common at base), rarely pyritic (fine and disseminated), cherty (?), moderately well washed, poorly cemented, but fairly well consolidated, top 7" has fair porosity, basal portion is tight. A few carbonaceous streaks, and laminations break this massive unit, bedding generally regular. Fairly well developed slickenside (45°).

1' 7" SANDSTONE, medium grey, tending to fine-grained at base, "salt and pepper", light grey speckled with black, abundant argillaceous material (kaolinitic ?) present as a loose cement or encrustation on the quartz grains, trace of intergranular bitumen, moderately well sorted, subrounded, occasionally subangular, poorly washed, poorly cemented, moderately well consolidated, fair to good intergranular porosity, possible faint oil staining. Faintly diagonally bedded (20°).

0' 5" SHALE, dark grey with occasional small "pockets" of sandstone, as above.

1' 0" DETRITUS, light grey to tan, composed of angular fragments (up to 1" across) of dolomite (?), chert (?), and kaolintic (?) material, all rotten, and very difficult to distinguish, with a matrix of sandstone, fine-grained, quartz, light grey, very poorly sorted, subangular to angular, poorly washed, poorly cemented, fair porosity, and possible slight oil stain. This unit shows no indication of bedding. Vugs on the surface of the core imparts a reefal aspect to the rock.

Core #42 - 6826' to 6835' - Recovered 9'

1' 10" SANDSTONE, medium-grained, occasionally fine-grained, "salt and pepper", medium brown grey, carbonaceous, abundant intergranular bitumen, moderately well sorted, subangular to subrounded, fairly well washed, poorly cemented, but fairly well consolidated, fair to good intergranular porosity with some dead oil staining, massive. (See Plate 5, Figures 4, 5 and 10).

1' 3" DETRITUS, light grey to tan, composed of angular fragments (up to 1 1/2") of quartz, chalcedony, dolomite (?), and argillaceous material (kaolinitic ?), all rotten, and difficult to identify, with a matrix of sandstone, as above. Contact with the overlying sandstone is at angle of approximately 20°, and with the underlying shale at about 45°. (See Plate 3, Figure 3).

0' 11" SHALE, pale green, pyritic (finely disseminated particles, and "threads") soapy bentonitic appearance mixed with detritus, as above. A few poorly developed slickensides occur in the unit.

6830' Top of Rundle Formation

5' 0" DOLOMITE, medium to coarse-crystalline, light grey with abundant intercrystalline dark brown oil staining. The surface of the core commonly has a dark buff to grey brown colour. Abundantly bituminous in places with fairly good porosity (intercrystalline, and microvugs) throughout ranging to good, massive.

Note: All cores were described using a binocular microscope with an enlargment of 12.5 times. For the identification of carbonate material, 5% (by weight) hydrochloric acid was employed.

APPENDIX B

LOCATION OF SAMPLES

I. Samples for Thin Section Study

Imperial Christmas Creek #11-10
Lsd. 11, Sec. 10, Twp. 62, Rge. 10 W5M
K.B.: 2817'

Sample Number	Depth below K.B. elevation (feet)
MXC-1 (4174)*	4852
MXC-9 (4175)	4898
MXC-12 (4176)	4908
MXC-14 (4177)	4913
MXC-17 (4178)	4931
MXC-19 (4179)	4944
MXC-22 (4180)	4958

Imperial Cynthia #14-28
Lsd. 14, Sec. 28, Twp. 52, Rge. 11 W5M
K.B.: 2940'

Sample Number	Depth below K.B. elevation (feet)
MCA-1 (4170)	6617
MCA-16 (4171)	6745
MCA-20 (4172)	6762
MCA-22 (4173)	6772

* Bracketed number refers to Department of Geology, University of Alberta, catalogue number for the prepared thin section.

Socony Seaboard Violet Grove #7-6
Lsd. 6, Sec. 7, Twp. 48, Rge. 7 W5M
K.B.: 2896'

Sample Number	Depth below K.B. elevation (feet)
SVG-3 (4181)*	6570
SVG-10 (4182)	6592
SVG-11 (4183)	6635
SVG-13 (4184)	6644
SVG-14 (4185)	6666
SVG-18 (4186)	6723
SVG-24 (4187)	6752
SVG-27 (4188)	6769
SVG-28 (4189)	6791
SVG-31 (4190)	6806
SVG-33 (4191)	6812
SVG-39 (4192)	6827

II. Samples for Heavy Accessory Mineral Study

Imperial Christmas Creek #11-10
Lsd. 11, Sec. 10, Twp. 62, Rge. 10 W5M
K.B.: 2817'

Sample Number	Depth below K.B. elevation (feet)
MXC-2	4857
MXC-10	4899
MXC-14	4913
MXC-18	4940
MXC-22 (phenoclasts only)	4956

* Bracketed number refers to Department of Geology, University of Alberta, catalogue number for the prepared thin section.

Imperial Cynthia #14-28
Lsd. 14, Sec. 28, Twp. 52, Rge. 11 W5M
K.B.: 2940'

Sample Number	Depth below K.B. elevation (feet)
MCA-2	6619
MCA-12	6727
MCA-17	6749
MCA-23	6778

Socony Seaboard Violet Grove #7-6
Lsd. 6, Sec. 7, Twp. 48, Rge. 7 W5M
K.B.: 2896'

Sample Number	Depth below K.B. elevation (feet)
SVG-4	6571
SVG-11	6635
SVG-14	6666
SVG-16	6719
SVG-26	6765
SVG-36	6820
SVG-39	6827

III. Sample of Glauconite Submitted for Age Date

Approximately 9 grams of glauconite were collected from an extremely glauconitic zone in a core from Socony Seaboard Violet Grove #7-6 between 6591 and 6594 feet below K.B. elevation. It occurs about 33 feet below the top of the "Glauconitic" sandstone member. This sample was submitted to Dr. H. Baadsgaard of the Department of Geology, University of Alberta for a physical age date determination.

APPENDIX C

SELECTED THIN SECTION DESCRIPTIONS

Sample Number: MXC-1 (Thin section number 4174)

Location: Imperial Christmas Creek #11-10 (11-10-62-10 W5)
Depth 4852 feet.

Megascopic Description: (see Plate 1, Figure 1)

SANDSTONE, very fine-grained, "salt and pepper", medium light grey, pyritic (sporadic nodules and streaks), slightly calcareous, slightly fossiliferous (a few broken shell fragments), moderately well to poorly sorted, subrounded, fairly well washed, moderately well indurated, tight. A few lenses of bentonitic carbonaceous (?) material occur sporadically.

Microscopic Description:

Texture: Moderately closely packed, detrital contacts are straight (slight penetration) to concavo-convex (moderate penetration).

Structure: Slight stratification by irregular subparallel streaks of dark (carbonaceous ?) material.

Main Constituents:

60% Quartz - grains are mainly subrounded, some are subangular and angular, average size 0.10 mm., about half of the particles show straining to some extent.

2% Chert - subrounded.

10% Argillaceous rock fragments - mainly angular, with some subangular dark brown to black shale fragments, generally larger than the quartz grains.

Feldspar -

2% Potash variety - subangular to rounded.
Trace Twinned plagioclase - angular.

Varietal Constituents: (>1%)

3% Carbonaceous material.

Accessory Constituents: ($\leqslant$ 1%)

1% Pyrite, Leucoxene, Tourmaline, Glauconite, Zircon, Sericite.

Matrix:

2% Quartz grains, and some clay.

Cement:

20% Carbonate - in places slightly replaces the quartz.

Trace Silica - overgrowths.

Classification: Lithic sandstone.

Sample Number: MXC-19 (Thin section number 4179)

Location: Imperial Christmas Creek #11-10 (11-10-62-10 W5)
Depth 4944 feet.

Megascopic Description:

SANDSTONE, very fine to fine-grained, slightly "salt and pepper", light grey with some light brownish grey mottling, calcareous, pyritic (irregular nodules and fine disseminated particles), slightly glauconitic, slightly argillaceous, poorly sorted, subrounded, fairly well washed, moderately well indurated, tight.

Microscopic Description:

Texture: Moderately closely packed, detrital contacts are mainly straight (slight penetration) with some concavo-convex (moderate penetration).

Structure: None apparent.

Main Constituents:

65% Quartz - mainly subrounded to subangular, average size 0.12 mm., with many particles about 0.20 mm. Approximately 20% of the grains show straining, the few overgrowths are poorly developed.

7% Chert - slightly better rounded than the quartz, many fragments are coarse mosaics, resembling a micro-quartzite.

5% Argillaceous rock fragments - subangular to subrounded, medium greyish brown to black, occasionally fractured and filled with microcrystalline quartz.

1% Feldspar - potash variety - present as small subrounded grains.

Varietal Constituents: (> 1%)

2% Pyrite - fine and disseminated, commonly forms dendritic patterns, also a few irregular nodules, authigenic (?).

Accessory Constituents: ($\leqslant$ 1%)

1% Carbonaceous matter, Glauconite, Leucoxene, Zircon, Tourmaline, Phosphatic material (?).

Matrix:

3% Quartz and clay.

Cement:

15% Carbonate - has replaced quartz, chert, and rock fragments occasionally.

1% Silica - overgrowths.

Classification: Lithic sandstone.

Sample Number: MCA-20 (Thin section number 4172)

Location: Imperial Cynthia #14-28 (14-28-52-11 W5)
Depth 6762 feet.

Megascopic Description:

SANDSTONE, quartz, very fine-grained, slightly "salt and pepper", light brownish grey mottled with light grey, slightly pyritic (fine and disseminated), well sorted, sub-rounded, well washed, fairly well indurated, tight. A few tiny irregular streaks and lenses of black calcareous shale, also a few small "pockets" of yellowish grey bentonitic clay material.

Microscopic Description:

Texture: Loosely to moderately well packed (patchy), poor intergranular porosity, detrital contacts are tangential (essentially no interpenetration) to concavo-convex (moderate penetration).

Structure: Irregular laminations due to local concentrations of fine and dark material.

Main Constituents:

83% Quartz - mainly subrounded, some subangular, average size 0.10 mm., a few grains have overgrowths. About 25% of the particles show effects of intense straining imparted before their present deposition.

1% Chert

2% Argillaceous rock fragments - subangular dark coloured particles of shale.

Trace Feldspar - sodic plagioclase variety.

Varietal Constituents: ($\geqslant$ 1%)

1% Carbonaceous material - concentrated in thin bands imparting a laminar aspect to some portions of this specimen.

Accessory Constituents: ($\leqslant$ 1%)

1% Pyrite, Leucoxene, Hematite, Limonite, Sericite.

Matrix:

3% Quartz and clay.

Cement:

7% Carbonate - patchy, common as tiny veinlets and crystals outlining quartz grains.

2% Silica - overgrowths.

Classification: Quartz sandstone.

Sample Number: SVG-10 (Thin section number 4182)

Location: Socony Seaboard Violet Grove #7-6 (6-7-48-7 W5)
Depth 6592 feet.

Megascopic Description: (see Plate 2, Figure 3).

SANDSTONE, glauconitic, very fine to fine-grained, "salt and pepper", medium grey streaked with dark greenish grey, pyritic (irregular large nodules, fine, and disseminated), slightly calcareous, moderately well to poorly sorted, sub-angular to subrounded, poorly to fairly well washed, well indurated, tight. Several tiny laminations of dark grey bentonitic shale indicate the bedding.

Microscopic Description:

Texture: Very loosely packed, detrital contacts are rare, these being mainly straight (slight penetration).

Structure: Bedding indicated by a faint banding of the finer fraction of material.

Main Constituents:

30% Quartz - angular to subrounded, about 0.15 mm. average diameter, shows some effects of straining.

5% Chert - subrounded to rounded.

7% Argillaceous rock fragments - subrounded, elongate, medium to dark brown shale and silty shale.

Trace Feldspar - potash variety.

Varietal Constituents: ($\geq$ 1%)

7% Glauconite - generally slightly larger than the quartz particles.

2% Pyrite - fine and disseminated, also some irregular small nodules.

2% Carbonaceous material.

Accessory Constituents: ($\leqslant$ 1%)

1% Leucoxene, Hematite.

Matrix:

45% Mainly quartz and chert fragments with some clay.

Cement:

1% Carbonate (patchy).

Classification: Argillaceous lithic sandstone.

Sample Number: SVG-14 (Thin section number 4185)

Location: Socony Seaboard Violet Grove #7-6 (6-7-48-7 W5)
Depth 6666 feet.

Megascopic Description:

SANDSTONE, very fine-grained, "salt and pepper", medium light grey, calcareous, pyritic (fine disseminated particles) fossiliferous (broken pelecypod shells) slightly argillaceous, moderately well to poorly sorted, subangular to subrounded, poorly to fairly well washed, well indurated, tight.

Microscopic Description:

Texture: Very loosely packed, detrital contacts are rare, tangential (essentially no interpenetration) where present.

Structure: Bedding indicated by streaks of fine fraction material.

Main Constituents:

30% Quartz - angular to subangular, some subrounded, average size 0.08 to 0.10 mm.

5% Chert - generally subangular to subrounded.

10% Argillaceous rock fragments - subangular, mainly elongate, medium to dark brown shale fragments.

2% Feldspar - potash variety.

Varietal Constituents: (> 1%)

2% Pyrite - fine and disseminated, also some small sub-round nodules.

1% Carbonaceous material.

Accessory Constituents: ($\leqslant$ 1%)

1% Hematite, Pelecypod shell fragments.

Matrix:

15% Mainly quartz, some chert fragments and clay.

Cement:

34% Carbonate.

Classification: Argillaceous lithic sandstone.

Sample Number: SVG-24 (Thin section number 4187)

Location: Socony Seaboard Violet Grove #7-6 (6-7-48-7 W5)
Depth 6752 feet.

Megascopic Description:

SANDSTONE, quartz, medium-grained, very slightly "salt and pepper", medium grey, very slightly argillaceous due to presence of tiny yellowish grey grains of clayey material, fairly well sorted, subrounded, moderately well to well washed, fairly well indurated, good intergranular porosity.

Microscopic Description: (see Plate 5, Figure 1).

Texture: Very closely packed, detrital contacts are concavo-convex (moderate interpenetration, some sutured (extreme interpenetration).

Structure: Faintly bedded, due to alignment of rock fragments.

Main Constituents:

84% Quartz - subrounded, shows a moderate amount of wavy extinction, average size 0.20 mm.

3% Chert

5% Argillaceous rock fragments - subangular to subrounded, medium to dark brown argillaceous material (shale), some show fractures filled with microcrystalline silica.

Trace Feldspar - potash variety, subrounded.

Varietal Constituents: ($>$ 1%)

2% Carbonaceous material - commonly forms a very fine film between the quartz particles.

Accessory Constituents: ($\leqslant$ 1%)

1% Pyrite - very fine and disseminated.

Matrix:

2% Quartz and clay.

Cement:

2% Silica - microcrystalline.

1% Pore space:

Classification: Quartz sandstone

Sample Number: SVG-31 (Thin section number 4190)

Location: Socony Seaboard Violet Grove #7-6 (6-7-48-7 W5)
Depth 6806 feet.

Megascopic Description:

SANDSTONE, quartz, fine to medium-grained, slightly "salt and pepper", light grey, slightly argillaceous (light to

yellowish grey particles), fairly well sorted, subrounded, moderately well to well washed, fairly well indurated, poor intergranular porosity.

Microscopic Description:

Texture: Very closely packed, detrital contacts are concavo-convex (moderate interpenetration) with some sutured (extensive interpenetration).

Structure: None apparent.

Main Constituents:

85% Quartz - subrounded, average size 0.20 mm., about 30% of the grains show some effects of straining. Approximately 10% have overgrowths.

3% Chert - subrounded to rounded.

7% Argillaceous rock fragments - consist of angular to subangular, light to dark brown particles of shale and silty shale. Slightly larger than the quartz grains.

Trace Feldspar - potash variety.

Accessory Constituents: ($\leqslant$ 1%)

1% Hematite, Carbonaceous matter (streaks and patches).

Matrix:

1% Quartz and clay.

Cement:

2% Silica - overgrowths.

1% Pore space:

Classification: Lithic sandstone.

Detailed Description of Rock Fragment Sandstones

A Swift Automatic Point Counter was used to determine accurately the relative abundance of constituents in four thin sections of rock fragment sandstones from the "Calcareous" and "Glauconitic" sandstone members. Four hundred counts were made on each section studied.

Sample Number: MXC-9 (Thin section number 4175)

Location: Imperial Christmas Creek #11-10 (11-10-62-10 W5)
Depth 4897 feet.

Megascopic Description:

SANDSTONE, very fine to fine-grained, "salt and pepper", medium light grey, pyritic (small irregular nodules, fine veinlets, and pyritized fossils), slightly calcareous, slightly fossiliferous (pyritized pelecypods), slightly carbonaceous, slightly kaolinitic(?) (sporadic irregular patches), poorly sorted, subangular, fairly well indurated, very poor porosity.

Microscopic Description:

Texture: Loosely packed, detrital contacts are tangential (essentially no interpenetration).

Structure: None apparent.

Main Constituents:

19.25% Quartz - fragments are angular to subrounded, average size 0.30 mm., some to 0.60 mm. The majority of the grains show some indication of straining, with many extensively strained; overgrowths are rare, and poorly developed.

Siliceous Rock Fragments

Chert - slightly better rounded than the quartz, average size 0.30 mm.

18.25% (i) "Normal" - colourless, fine mosaic-like texture.

3.00% (ii) Coarse-grained - mainly colourless.

3.50% (iii) Coloured - fine mosaic-like texture, medium to dark grey.

6.00% Metaquartzite - composite quartz particles with extreme undulatory extinction.

Argillaceous Rock Fragments - subangular, average size 0.25 mm., some grains are fractured, fractures are filled with carbonate or with microcrystalline quartz.

5.00% (i) Shale - medium grey.

2.25% (ii) Silty shale - mainly medium grey, with silt-size particles of quartz.

5.25% (iii) Carbonaceous shale - dark brown, often almost opaque.

3.50% (iv) Phyllite or argillite - abundant phyllosilicate minerals.

0.50% Feldspar - potash variety.

Varietal Constituents: ($\geqslant$1%)

1.00% Pyrite.

Accessory Constituents: ($\leqslant$1%)

0.25% Bitumen

Matrix:

4.00% Fine quartz and chert particles.

6.75% Fragments of argillite, shale, and clay.

Cement:

21.00% Carbonate - has replaced quartz, chert, and argillaceous rock fragments extensively on their edges, also has attacked the silica overgrowths.

Trace Silica - overgrowths on quartz.

0.50% Pore Space:

Classification: Argillaceous rock fragment sandstone.

Sample Number: MCA-1 (Thin section number 4170)

Location: Imperial Cynthia #14-28 (14-28-52-11 W5)
Depth 6616 feet.

Megascopic Description:

SANDSTONE, very fine to fine-grained, "salt and pepper", medium light grey, glauconitic, bituminous, micromicaceous, slightly argillaceous, poorly to moderately well sorted, subrounded, fairly well indurated, tight. Bedding is indicated by the sporadic alignment of a few dark coloured particles.

Microscopic Description:

Texture: Loosely packed, detrital contacts are straight (slight interpenetration).

Structure: None apparent.

Main Constituents:

26.50% Quartz - most grains are subangular to subrounded, a few are angular, average size 0.10 to 0.20 mm., about 50% of the grains show varying degrees of wavy extinction.

Siliceous Rock Fragments

Chert - subangular to subrounded, usually slightly larger than the quartz grains.

6.50% (i) "Normal" - colourless, fine mosaic-like texture.

0.50% (ii) Coarse-grained - mainly colourless.

3.50% (iii) Coloured - fine mosaic-like texture, medium to dark grey.

8.00% Metaquartzite - composite quartz particles with undulatory extinction.

Argillaceous Rock Fragments - subangular to subrounded.

3.75% (i) Shale - medium grey.

5.25% (ii) Silty shale - dark brown-grey shale with silt-size quartz particles.

8.75% (iii) Carbonaceous shale - dark brown to opaque.

4.25% (iv) Phyllite or argillite - phyllosilicate minerals.

Varietal Constituents: ($\geqslant$1%)

1.00% Bitumen

Accessory Constituents: ($\leqslant$1%)

0.50% Glauconite.

0.25% Sericite.

Trace Zircon, Leucoxene.

Matrix:

10.50% Fine quartz and chert particles.

6.50% Fragments of argillite, shale and clay.

Cement:

7.50% Carbonate

0.50% Silica - overgrowths on quartz.

6.25% Pore Space:

Classification: Argillaceous rock fragment sandstone.

Sample Number: SVG-3 (Thin section number 4181)

Location: Socony Seaboard Violet Grove #7-6 (6-7-48-7 W5)
Depth 6570 feet.

Megascopic Description:

SANDSTONE, fine-grained, "salt and pepper", light grey, glauconitic, fairly well sorted, subangular to subrounded, fairly well indurated, poor patchy porosity.

Microscopic Description:

Texture: Loosely to moderately well packed, detrital contacts are straight (slight interpenetration) to concavo-convex (moderate interpenetration).

Structure: None apparent.

Main Constituents:

40.00% Quartz - angular to subrounded, average size 0.20 mm., shows moderate degree of straining.

Siliceous Rock Fragments

Chert

5.75% (i) "Normal" - colourless, fine mosaic-like texture.

5.00% (ii) Coarse-grained - colourless.

5.25% (iii) Coloured - medium to dark grey.

2.75% Metaquartzite - composite quartz particles with wavy extinction.

Argillaceous Rock Fragments - subangular.

4.00% (i) Shale - medium grey.

4.25% (ii) Silty shale - medium grey with silt-size quartz particles.

11.75% (iii) Carbonaceous shale - dark brown to opaque.

5.75% (iv) Phyllite or argillite - phyllosilicate minerals.

0.25% Feldspar - potash variety.

Varietal Constituents: ($\geqslant$1%)

2.50% Glauconite - rounded to subrounded, average size 0.15 mm.

Accessory Constituents: ($\leqslant$1%)

0.50% Pyrite.

0.50% Sericite.

Matrix:

4.25% Fine quartz and chert particles.

1.75% Clay.

Cement:

1.25% Silica - overgrowths on quartz and microcrystalline.

4.50% Pore Space:

Classification: Rock fragment sandstone.

Sample Number: SVG-18 (Thin section number 4186)

Location: Socony Seaboard Violet Grove #7-6 (6-7-48-7 W5)
Depth 6724 feet.

Megascopic Description:

SANDSTONE, very fine to fine-grained, "salt and pepper", medium light grey, slightly calcareous, slightly pyritic (fine and disseminated), moderately well sorted, angular to subangular, well indurated, hard, tight. Faint stratification indicated by alignment of dark particles.

Microscopic Description:

Texture: Loosely packed, detrital contacts are straight (slight interpenetration) to concavo-convex (moderate interpenetration) with a few sutured (extensive interpenetration).

Structure: Faintly laminated by alignment of dark coloured rock fragments and subparallel position of elongate grains.

Main Constituents:

25.75% Quartz - angular to subrounded, 0.20 to 0.30 mm. in diameter, more than 50% show moderately wavy extinction.

Siliceous Rock Fragments

Chert - subrounded to rounded, average size 0.30mm.

6.50% (i) "Normal" - colourless, fine mosaic-like texture.

2.50% (ii) Coarse-grained - mainly colourless.

4.50% (iii) Coloured - medium to dark grey.

11.25% Metaquartzite - composite quartz grains with undulatory extinction.

Argillaceous Rock Fragments - subangular to subrounded, some are fractured and filled with silica cement which partly replaces the phenoclasts.

6.25% (i) Shale - medium grey.

5.00% (ii) Silty shale - medium to dark grey with silt-size quartz particles, slightly micaceous.

5.25% (iii) Carbonaceous shale - dark brown, to black, opaque.

7.00% (iv) Phyllite or argillite - abundant phyllo-silicate minerals.

Varietal Constituents: ($\geqslant$1%)

2.00% Pyrite.

Accessory Constituents: ($\leqslant$1%)

0.25% Bitumen.

Trace Sericite.

Matrix:

2.25% Fine quartz and chert particles.

5.75% Clay, shale, and argillite fragments.

Cement:

12.25% Carbonate.

1.25% Silica - overgrowths on quartz, some microcrystalline pore filling.

2.25% Pore Space:

Classification: Rock fragment sandstone.

APPENDIX D

IDENTIFICATION OF FOSSILS

The following fossils were identified by Dr. C. R. Stelck.

Imperial Christmas Creek #11-10

Lsd. 11, Sec. 10, Twp. 62, Rge. 10 W5M

K.B.: 2817'

4839' ?*Sphaerium* sp.

4843' ?*Anodonta* sp.
Fish scales and fish bones (cycloid).

4844' Fish scales.

4848' *Murraia naiadiformis* Russell
Fish scales.

4849' Fish teeth, bones, and scales.

4850' ?*Sphaerium* sp.

4855' ?*Anodonta* sp.
Murraia sp. cf. *M. naiadiformis* Russell
?*Sphaerium* sp.

4860' ?*Murraia* sp.

4861' *Melania* sp. cf. *M. multorbis*? Russell
Unio n. sp. (*Pleurobema* sp.)

4865' ?*Cardium* sp.
Murraia sp. cf. *M. naiadiformis* Russell
Nucula sp. cf. *N. athabaskensis* McLearn

4866' ?*Cardium* sp.
Nucula sp.

4867' ?*Cardium* sp.
Murraia sp. cf. *M. naiadiformis* Russell
Nucula sp.

4868'	?*Tellina* sp. *Thracia* sp. *Unio* (*Pleurobema* sp.)
4869'	?*Thracia* sp. *Murraia* sp. cf. *M. naiadiformis* Russell *Cardium* sp.
4870'	*Cardium* sp. Fish bone. ?*Murraia* sp. ?*Pteria* sp.
4871'	*Viviparus* sp. *Pleurobema* sp.
4873'	?*Murraia* sp. *Brachidontes* sp. aff. *B. athabaskensis* McLearn
4886'	*Murraia* sp. cf. *M. naiadiformis* Russell
4887'	*Murraia* sp.
4889'	Ostracods.
4896'	Ostracods. Fish bones, and scales.
4898'	Ostracods. Fish bones.
4903'	Plant remains, indet.
4927'	*Elatides splendida* Bell ?*Pterophyllum* sp. *Elatides* sp. *Nilssonia* sp. *Sphenopteris* sp. cf. *S. latiloba* Fontaine
4947'	*Scalez* sp.
4961'	Piece of bark.
4965'	*Ginkgo* sp. *Athrotaxites* sp. cf. *A. berryi* Bell

Imperial Cynthia #14-28

Lsd. 14, Sec. 28, Twp. 52, Rge. 11 W5M

K.B.: 2940'

6636' ?Anodonta sp.
Parmicorbula sp.
Murraia sp. aff. M. naiadiformis Russell
?Lioplacodes sp. cf. L. bituminis Russell
?Goniobasis sp.
Fish plate.

6637' Murraia naiadiformis Russell
?Goniobasis sp.
?Thracia sp. cf. T. kissoumi McLearn

6638' Fish scale.

6642' Unio n. sp. A (Pleurobema sp.)
Goniobasis sp.
?Lioplacodes sp.

6644' Unio n. sp. B (Pleurobema sp.).
Estherid? A
Lioplacodes sp. cf. L. bituminis Russell
?Murraia sp.

6647' Estherid? A
Murraia sp.

6649' Murraia sp.
Unio n. sp. A (Pleurobema sp.).
Sphaerium sp.
Estherid? A
Viviparus sp.
Murraia naiadiformis Russell
?Lioplacodes sp.

6650' ?Onestia sp.
?Pleurobema sp.
Viviparids?
?Murraia sp.

6712' Fossil wood.

Socony Seaboard Violet Grove #7-6

Lsd. 6, Sec. 7, Twp. 48, Rge. 7 W5M

K.B.: 2896'

6598' *Murraia* sp.
Thracia sp. cf. *T. kissoumi*? McLearn
Murraia sp. D

6601' *Murraia* sp. D

6602' *Murraia* sp. cf. *M. naiadiformis* Russell

6606' *Murraia* sp. cf. *M. naiadiformis* Russell

6608' *Murraia* sp. cf. *M. naiadiformis* Russell

6611' *Thracia* sp. cf. *T. kissoumi* McLearn

6614' *Murraia naiadiformis* Russell
Unio n. sp. B (cf. ?*Pleurobema* sp.).
Viviparus sp. cf. *V. murraiensis* Russell

6617' *Elliptio* sp. cf. *E. biornatus* (Russell)

6623' *Melania* sp. cf. *M. multorbis* Russell
?*Viviparus* sp.

6624' *Sphaerium* sp. A

6626' *Sphaerium* sp. A
Parateinostoma sp. indet.
Brachidontes sp. cf. *B. athabaskensis* McLearn
Murraia sp. cf. *M. naiadiformis* Russell
Onestia sp. cf. *O. onestae* (McLearn)

6627' *Sphaerium* sp. A (larger)
Sphaerium sp. B
Murraia sp. cf. *M. naiadiformis* Russell
?*Onestia* sp.

6628' *Onestia* sp. cf. *O. onestae* (McLearn)
Brachidontes n. sp.
Brachidontes sp. cf. *B. athabaskensis* McLearn
Cycloid scale.
Parateinostoma sp. indet.

?Thracia sp.
?Yoldia sp.
Viviparus sp. aff. V. murraiensis Russell (dwarf)
?Sphaerium sp.
Estherid? A

6629' Murraia sp. aff. M. naiadiformis Russell (shape something like M. fabensis)

6630' Sphaerium sp.
Fish scale.
Murraia sp. aff. M. naiadiformis Russell
Estherid? A

6631' Sphaerium sp.
?Lioplacodes sp.
Estherid? A

6633' Ostracods.

6634' Big fish scale. (Cycloid)
Ostracods.
Melania sp. cf. M. multorbis Russell
Sphaerium sp.

6649' ?Unio sp. (large)
?Melania sp.

6651' ?Sphaerium sp.

6654' Fish bone.
Scalez sp.

6655' ?Unio sp.
Onestia sp. cf. O. onestae? (McLearn)

6656' Unio biornatus Russell
?Onestia sp. cf. O. onestae (McLearn)
Sphaerium sp.
?Carinulorbis sp.
Scalez.
Melania sp. aff. M. multorbis Russell
Murraia sp.

6657' ?Onestia sp.

6659' Elliptio sp.
Unio sp.

6661'	Sphaerium sp. cf. Eupera onestae (McLearn) Onestia sp. cf. O. onestae (McLearn) ?Arctica sp.
6668'	Wood fragments. Melania sp.
6669'	Pelecypod, indet.
6675'	?Goniobasis sp.
6691'	Corbula sp. cf. C. palliseri McLearn Sphaerium sp. cf. Eupera onestae (McLearn) Campeloma sp.
6693'	Elliptio sp. cf. E. hamili (McLearn)
6704'	Plant fragments.
6710'	Podozamites sp. cf. P. stenopus Lesquereux Podozamites sp. A ?Ruffordia sp. cf. Sphenopteris gopperti (Dunker) Seward Scalez sp.
6716'	Podozamites sp. A
6720'	?Equisetum sp.
6738'	?Viviparus sp. indet.
6770'	Pityophyllum nordenskioldi (Heer)
6776'	Carpolithus sp.
6781'	Scalez sp.
6784'	Worm burrowings.

EXPLANATION OF PLATE 1

Photographs of Core

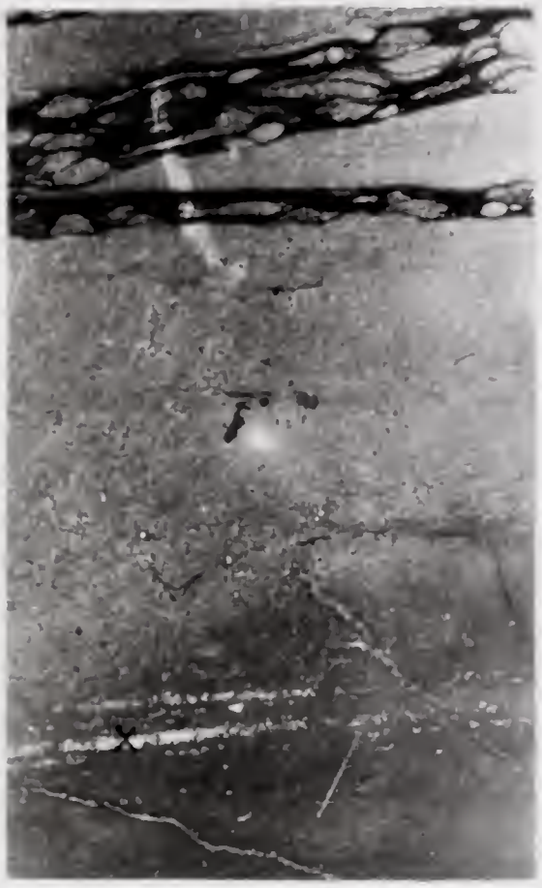
Figure 1: Sandstone, very fine-grained, slightly "salt and pepper", showing an intraformational conglomerate set in black shale, and at "X", streaks of pyrite; Imperial Christmas Creek #11-10, depth 4852 feet; thin section description page XXVIII; (x1).

Figure 2: Sandstone, very fine-grained, slightly "salt and pepper", irregularly intermixed with thin laminations of black shale; Imperial Christmas Creek #11-10, depth 4877 feet; (x1).

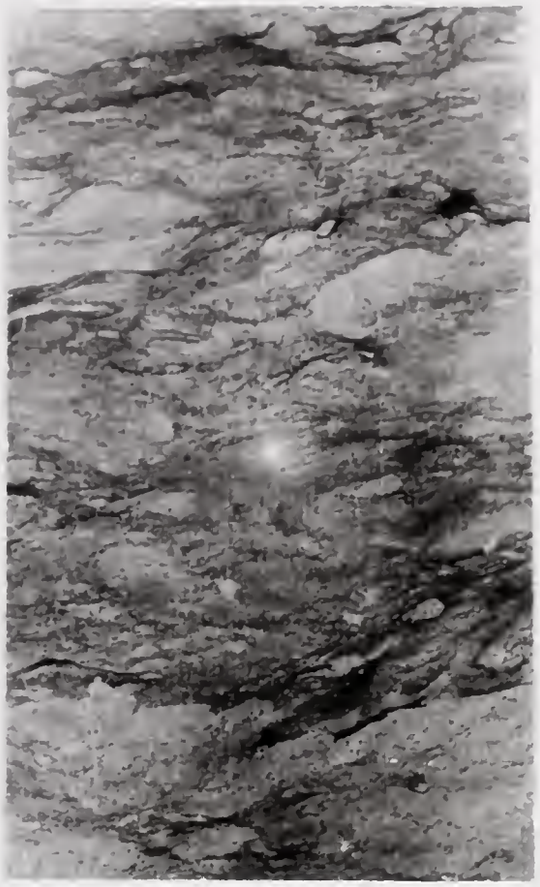
Figure 3: Siltstone and shale irregularly thinly interlaminated with very thin beds of very fine-grained, "salt and pepper" sandstone, pyrite nodule at "X", and coal parting at "Y"; Imperial Christmas Creek #11-10, depth 4905 feet; (x1).

Figure 4: Sandstone, very fine-grained, faintly laminated, showing worm burrowings(?), overlain by pyrite which has cemented and replaced the quartz (see Plate 4, Figure 1). This in turn was overlain by 1 foot of coal; Imperial Christmas Creek #11-10, depth 4908 feet; see Plate 4, Figure 1; (x1).

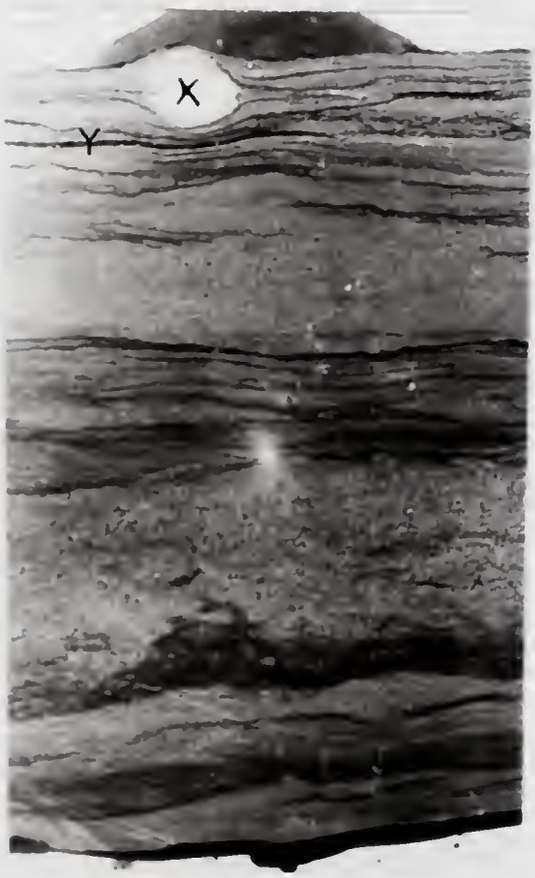
All samples are from the lower Mannville group.



1



2



3

4

PLATE 1

EXPLANATION OF PLATE 2

Photographs of Core

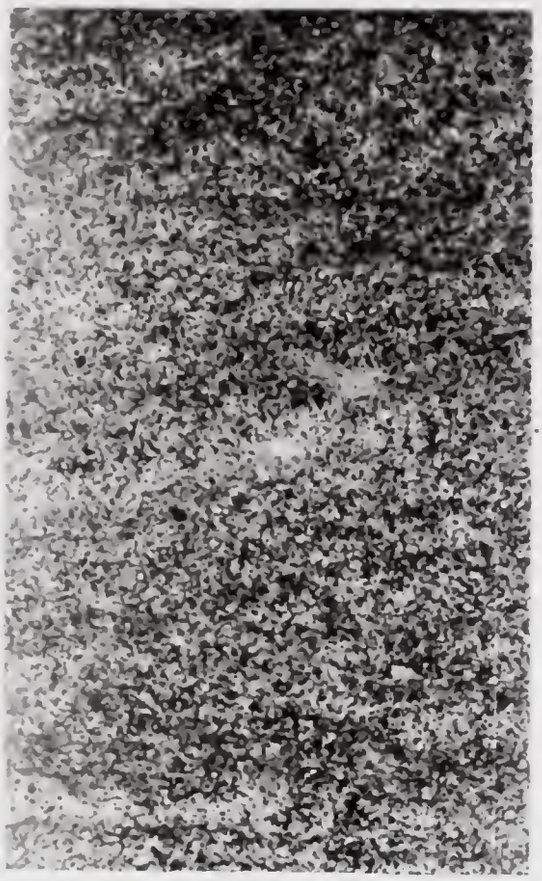
Figure 1: Sandstone, medium to coarse-grained, "salt and pepper", calcareous; Socony Seaboard Violet Grove #7-6, depth 6643 feet; see Plate 4, Figures 11 and 12; Plate 5, Figures 6, 7, 8, 9, 11 and 12; (x1.2).

Figure 2: Sandstone, fine to medium-grained, "salt and pepper", showing a stylolite; Socony Seaboard Violet Grove #7-6, depth 6641 feet; (x1.2).

Figure 3: Glauconitic sandstone, fine-grained, worm burrowing(?) at "X" is medium green in colour, several irregular nodules of pyrite are shown (e.g. "Y"); Socony Seaboard Violet Grove #7-6, depth 6593 feet; thin section description page XXXII; (x1.2).

Figure 4: Sandstone, very fine to fine-grained, showing irregular partings and laminations of black shale; Socony Seaboard Violet Grove #7-6, depth 6759 feet; (x1.2).

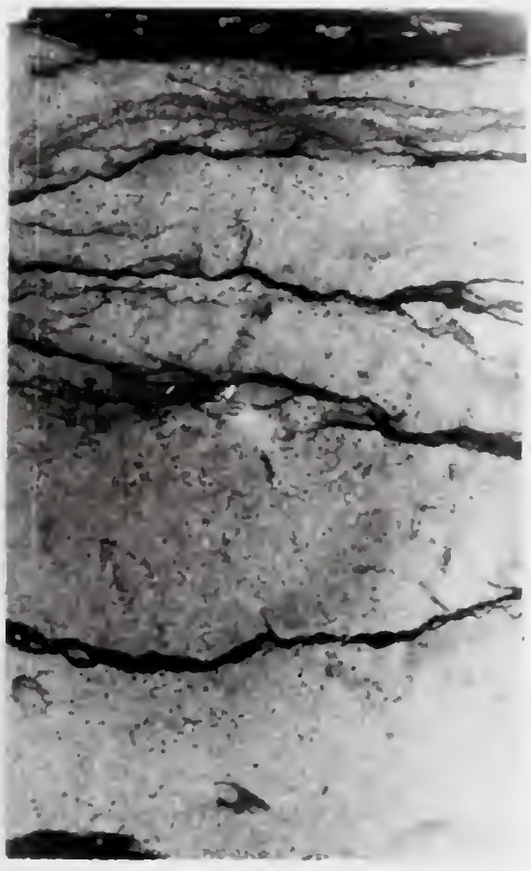
All samples are from the lower Mannville group.



1

2

3



4

PLATE 2

EXPLANATION OF PLATE 3

Photographs of Core

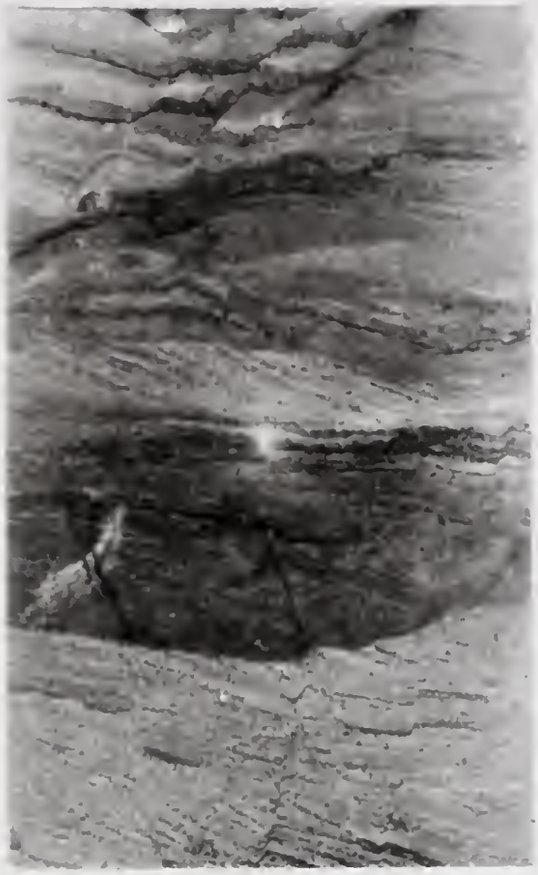
Figure 1: Sandstone, siltstone, and shale intermixed showing cross laminations and evidence of contortion; Socony Seaboard Violet Grove #7-6, depth 6816 feet; (x1.2).

Figure 2: Intraformational conglomerate, fine-grained "salt and pepper" sandstone pebbles with dark brownish grey shale matrix. Note stylolitic boundaries and interpenetrations of the phenoclasts (e.g. "X"); Imperial Christmas Creek #11-10, depth 4958 feet; see Plate 4, Figures 3 and 4; (x1).

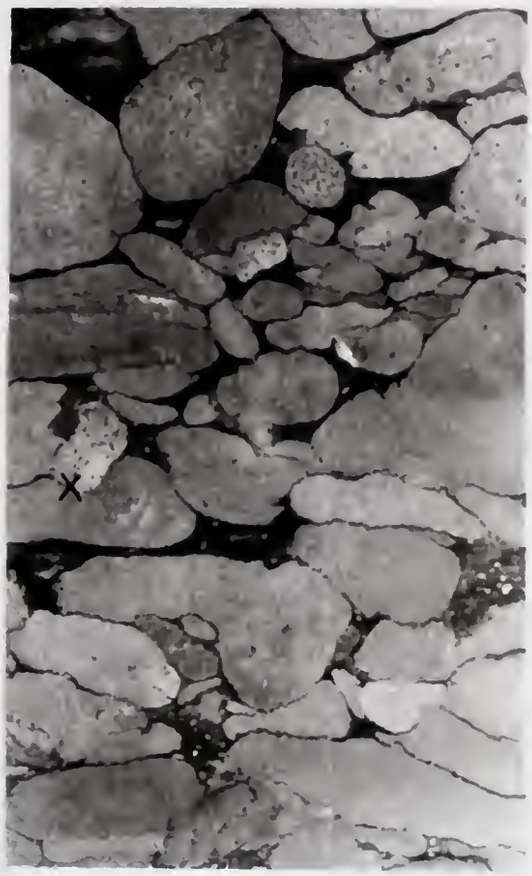
Figure 3: Detrital zone; this specimen is relatively well indurated, with chert fragments (e.g. "X") and extensively weathered argillaceous sandstone particles (e.g. "Y") set in a matrix of medium to coarse-grained sandstone; Socony Seaboard Violet Grove #7-6, depth 6828 feet; (x1.2).

Figure 4: Calcareous siltstone and shale (black) irregularly intermixed and indicating a local dip (slump structure ?), broken pelecypod shells at "X". The siltstone occasionally forms lenses (e.g. "Y"); Imperial Cynthia #14-28, depth 6632 feet; (x1).

All samples are from the lower Mannville group.

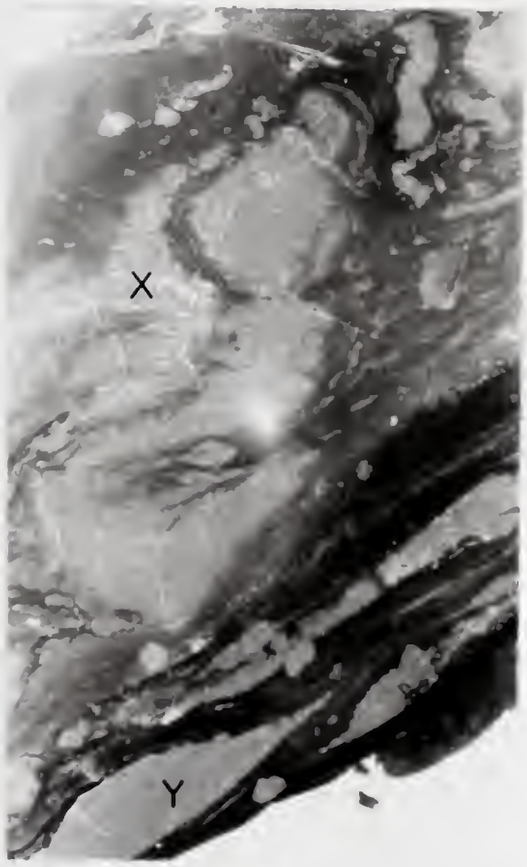


1



2

3



4

PLATE 3

EXPLANATION OF PLATE 4

Photomicrographs of Thin Sections

Figure 1: Section 4176; pyrite ("X") cementing and replacing quartz (white mineral) in a very fine-grained lithic sandstone, leaving angular particles of quartz "floating", plane polarized light; Imperial Christmas Creek #11-10, depth 4908 feet; see Plate 1, Figure 4; (x38).

Figure 2: Section 4177; very fine-grained quartz sandstone with patches of carbonate cement (e.g. "X") replacing the quartz, X-nicols; Imperial Christmas Creek #11-10, depth 4913 feet; (x97).

Figure 3: Section 4180; top and bottom are portions of phenoclasts of a conglomerate, the matrix of moderate brown clayey material ("X") holds several fragments of quartz (e.g. "Y"), with pyrite at "Z", plane polarized light; Imperial Christmas Creek #11-10, depth 4956 feet; see Plate 3, Figure 2; (x38).

Figure 4: Section 4180; detail of sandstone pebble (see Plate 3, Figure 2), fine material is chalcedony and micro-crystalline quartz cementing the larger quartz particles of a very fine-grained quartz sandstone; X-nicols; Imperial Christmas Creek #11-10, depth 4956 feet; see Plate 3, Figure 2; (x97).

Figure 5: Section 4170; very fine-grained lithic sandstone, with quartz (white), shale and siltstone phenoclasts and clayey matrix, plane polarized light; Imperial Cynthia #14-28, depth 6617 feet; (x97).

Figure 6: Section 4171; very fine-grained quartz sandstone with patches of carbonate cement (e.g. "X") and a silica over-growth ("Y"). Many of the quartz fragments contain minute dust-like inclusions (e.g. "Z"), X-nicols; Imperial Cynthia #14-28, depth 6745 feet; (x97).

Figure 7: Section 4173; abundant carbonate cement (tiny particles) in a loosely packed fine-grained argillaceous quartz sandstone, X-nicols; Imperial Cynthia #14-28, depth 6772 feet; (x97).

Figure 8: Section 4181; fine-grained rock fragment sandstone, with quartz particles (white) and silty shale rock fragments (black with tiny specks of white, "X"), X-nicols; Socony Seaboard Violet Grove #7-6, depth 6570 feet; (x38).

Figure 9: Section 4183; fine to medium-grained lithic sandstone showing fractured dark brown shale fragment filled with microcrystalline quartz ("X"). Rock fragments slightly larger than the quartz grains, plane polarized light; Socony Seaboard Violet Grove #7-6, depth 6635 feet; (x38).

Figure 10: Section 4183; quartz grains with sutured contacts (center) in a matrix of small particles of quartz and clayey material (e.g. "X"), plane polarized light; Socony Seaboard Violet Grove #7-6, depth, 6635 feet; (x80).

Figure 11: Section 4184; microcrystalline quartz filling fractures in a dark coloured chert fragment in medium to coarse-grained rock fragment sandstone; X-nicols; Socony Seaboard Violet Grove #7-6, depth 6644 feet; (x97).

Figure 12: Section 4184; off-set fracture in a shale fragment that is rimed with carbonaceous(?) material, carbonate cement ("X"), plane polarized light; same section as Figure 11; (x38).

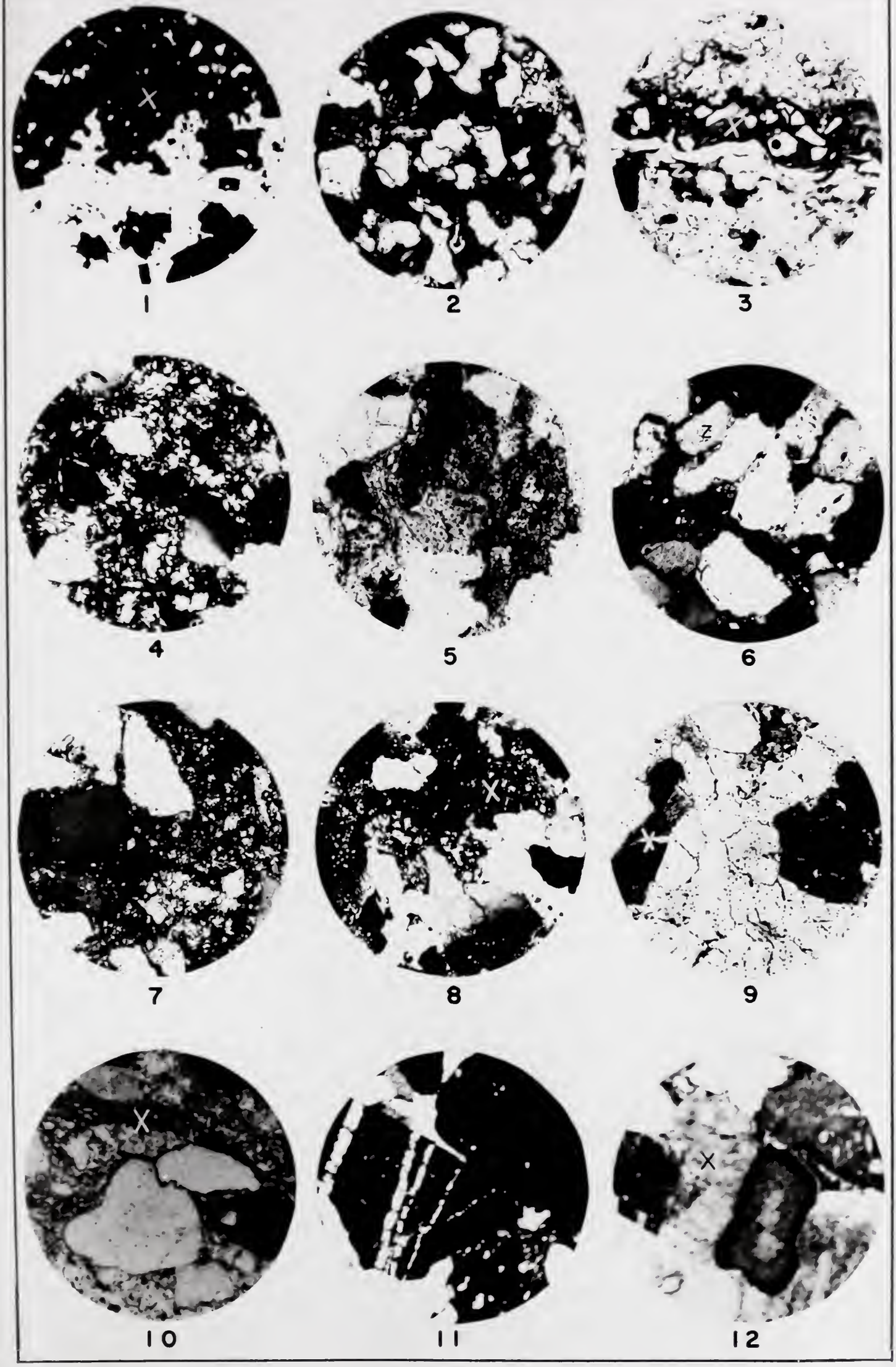


PLATE 4

EXPLANATION OF PLATE 5

Photomicrographs of Thin Sections

Figure 1: Section 4187; closely packed, medium-grained quartz sandstone, with silica overgrowth ("X") on a well rounded fragment of quartz; X-nicols; Socony Seaboard Violet Grove #7-6, depth 6752 feet; (x97).

Figure 2: Section 4188; silica overgrowth ("X") on a well rounded quartz grain in very closely packed fine to medium-grained quartz sandstone, X-nicols; Socony Seaboard Violet Grove #7-6, depth 6769 feet; (x38).

Figure 3: Section 4191; chert fragment ("X") in fine to medium-grained lithic sandstone, X-nicols; Socony Seaboard Violet Grove #7-6, depth 6812 feet; (x38).

Figure 4: Section 4192; microstylolitic contacts between quartz grains and a fragment of shale in fine to medium-grained lithic sandstone. Note the insoluble carbonaceous(?) material along the contacts (e.g. "X"), X-nicols; Socony Seaboard Violet Grove #7-6, depth 6827 feet; (x38).

Figure 5: Section 4192; microstylolitic contact between quartz grains and a shale fragment in sandstone as above; plane polarized light; (x80).

Figure 6: Section 4184; microstylolitic contact between very carbonaceous shale (black) and grey shale in medium to coarse-grained rock fragment sandstone; plane polarized light; Socony Seaboard Violet Grove #7-6, depth 6644 feet; (x97).

Figure 7: Section 4184; microstylolitic contact between two particles of grey shale in sandstone as above; plane polarized light; (x97).

Figure 8: Section 4184; quartz fragment having microstylolitic contacts with two particles of carbonaceous shale in sandstone as above; plane polarized light; (x80).

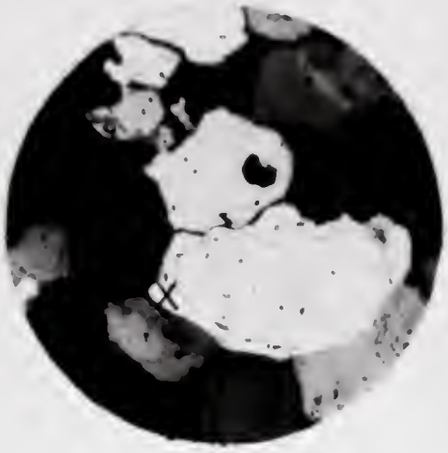
Figure 9: Section 4184; carbonaceous shale fragment with microstylolitic contacts with quartz ("X") and grey shale ("Y"); plane polarized light; (x38).

Figure 10: Section 4192; microstylolitic contact between quartz ("X") and grey shale ("Y") particles with dark brown to black insoluble residue on the contact, plane polarized light; Socony Seaboard Violet Grove #7-6, depth 6812 feet; (x38).

Figure 11: Section 4184; microstylolitic contacts at "X" and "Y" between carbonaceous shale (black) and grey shale ("X" and "Y") and quartz ("Z"), and carbonate ("A"), in sandstone the same as Figure 6; plane polarized light; (x38).

Figure 12: Section 4184; microstylolite between shale fragments (one slightly more carbonaceous than the other) showing the dark brown insoluble residue along the contact; plane polarized light; (x97).

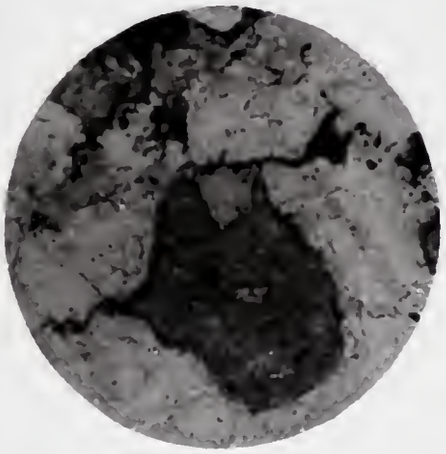
1



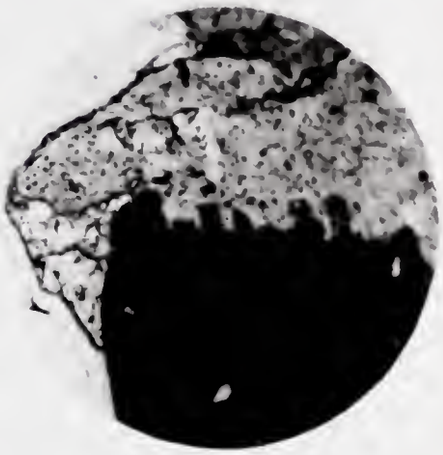
2

3

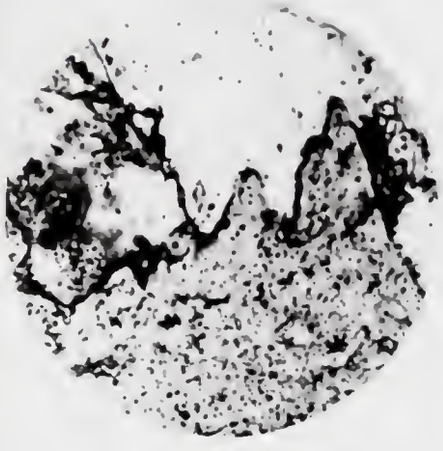
4



5

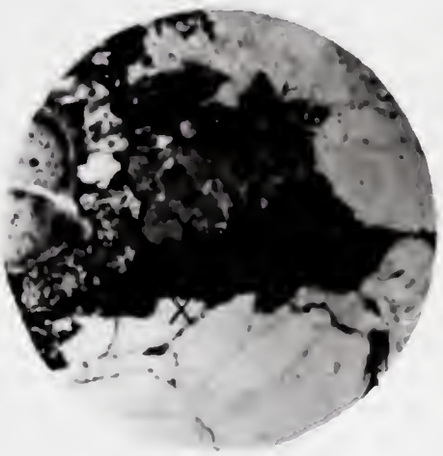


6

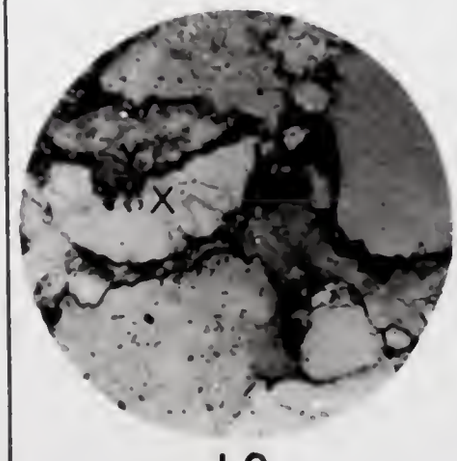


7

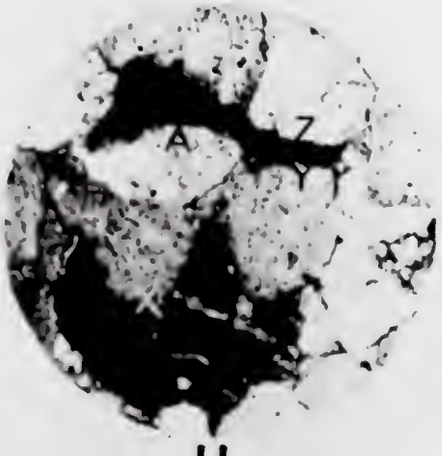
8



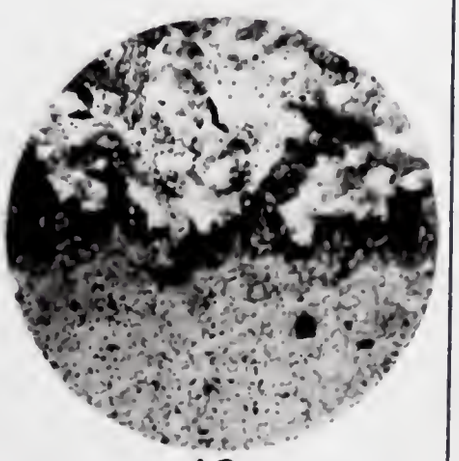
9



10



11



12

PLATE 5

EXPLANATION OF PLATE 6

Photomicrographs of Heavy Minerals

Figure 1a: Apatite, subangular, colourless, with tiny spherical inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-11; (x230).

Figure 1b: Apatite, subrounded, colourless, prismatic with spherical inclusions; Imperial Cynthia #14-28; sample MCA-2; (x230).

Figure 1c: Apatite subangular, colourless, with inclusions; Imperial Cynthia #14-28; sample MCA-2; (x230).

Figure 1d: Apatite, subangular, colourless, with inclusions; Imperial Cynthia #14-28, sample MCA-17; (x230).

Figure 2a: Barite, subangular, colourless, containing irregular and indistinct carbonaceous inclusions; Imperial Cynthia #14-28, sample MCA-2; (x230).

Figure 2b: Barite, angular, colourless, with carbonaceous inclusions; Imperial Cynthia #14-28, sample MCA-17; (x230).

Figure 3a: Rutile, subrounded, yellow-brown; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 3b: Rutile, knee-shaped twin, subangular, subhedral, yellow-brown, with a few inclusions; Imperial Cynthia #14-28, sample MCA-2; (x230).

Figure 3c: Rutile, subangular, subhedral, elongate, yellow-brown, note bearly visible inclined striations; Socony Seaboard Violet Grove #14-28; sample SVG-36; (x230).

Figure 3d: Rutile, subrounded, elongate, yellow-brown; Socony Seaboard Violet Grove #7-6; sample SVG-36; (x230).

Figure 4a: Collophane, yellow-brown, speckling may be due to haversian canals and/or lacunae; Imperial Cynthia #14-28; sample MCA-2; (x230).

Figure 4b: Collophane, yellow-brown; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 5a: Siderite, subangular, colourless, speckling may be brown spots of alteration; Imperial Cynthia #14-28, sample MCA-2; (x230).

Figure 5b: Siderite, angular, colourless, with brown spots of alteration(?); Imperial Cynthia #14-28, sample MCA-17; (x230).

Figure 6a: Tourmaline, light brown, pleochroic to pinkish brown, subangular; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 6b: Tourmaline, greyish olive, rounded, elongate; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 6c: Tourmaline, greyish olive, pleochroic to light olive-grey, angular, some minute inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 6d: Tourmaline, greyish olive, pleochroic to colourless, subrounded, subhedral; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 6e: Tourmaline, moderate brown, pleochroic to colourless, subrounded, subhedral, a few small carbonaceous inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 6f: Tourmaline, bluish grey, pleochroic to colourless, subrounded, inclusion may be seen at "X"; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 6g: Tourmaline, moderate brown, pleochroic to light brown, rounded, contains numerous irregular carbonaceous inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 6h: Tourmaline, dusky blue green, only slightly pleochroic, rounded, contains several irregular carbonaceous inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 6j: Tourmaline, olive grey, well rounded, contains some relatively large inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 7a: Zircon, subrounded, subhedral, elongate, colourless with inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 7b: Zircon, rounded, colourless, with an abraded overgrowth(?); Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 7c: Zircon, subrounded, subhedral, elongate, zoned, colourless; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 7d: Zircon, well rounded, colourless, with slightly pitted surface; Socony Seaboard Violet Grove #7-6, sample SVG-36; (x230).

Figure 7e: Zircon, angular, euhedral, elongate, colourless, shows pyramidal terminations; Socony Seaboard Violet Grove #7-6, sample SVG-14; (x230).

Figure 7f: Zircon, well rounded, elongate, colourless with pitted surface; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 7g: Zircon, rounded, colourless, slightly pitted surface; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 7h: Zircon, subangular, colourless, with inclusion; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

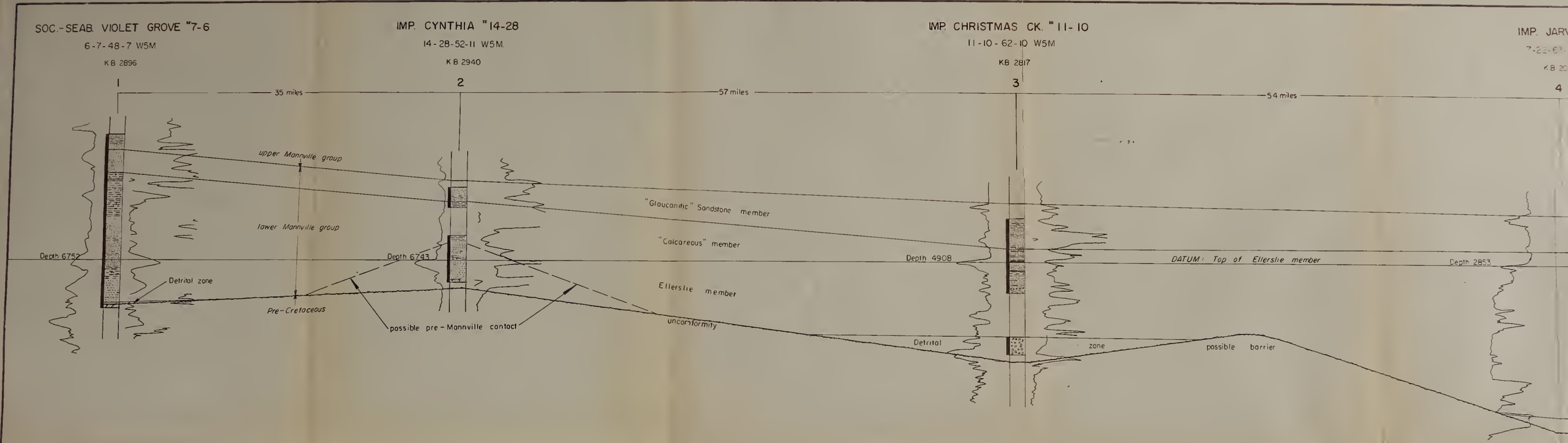
Figure 7j: Zircon, subrounded on one end, angular on the other, subhedral, elongate colourless, with a few carbonaceous inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-36; (x230).

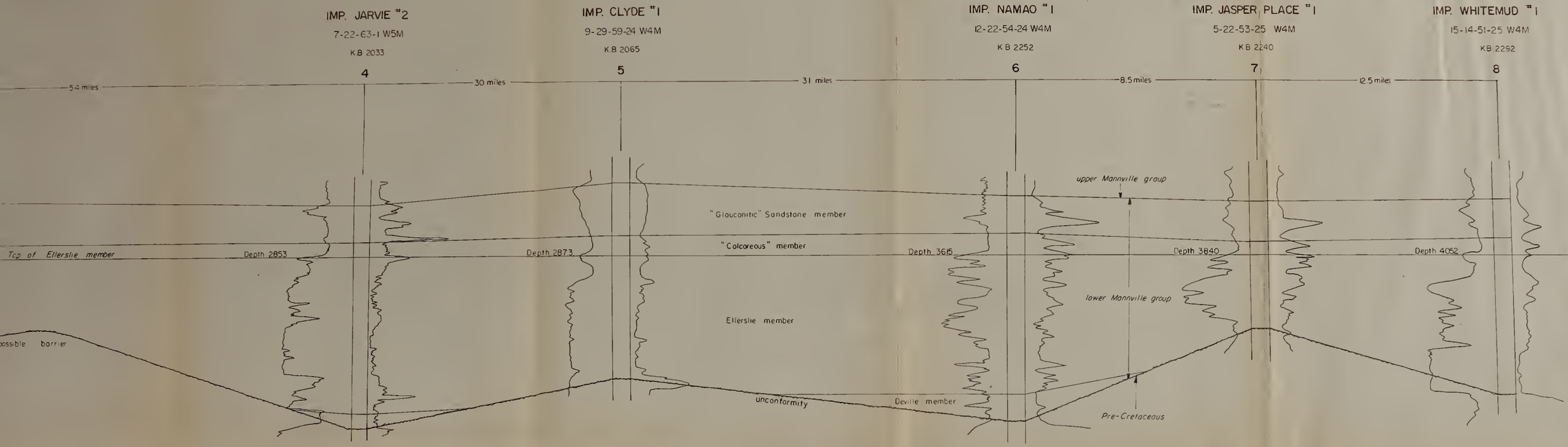
Figure 7k: Zircon, subrounded, elongate, colourless, showing several relatively large inclusions; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).

Figure 7m: Zircon, angular, euhedral, elongate, colourless, shows pyramidal terminations; Socony Seaboard Violet Grove #7-6, sample SVG-39; (x230).


1a
1b
1c
1d
2a
2b
3a
3b
3c
3d
4a
4b
5a
5b
6a
6b
6c
6d
6e
6f
6g
6h
6j
7a
7b
7c
7d
7e
7f
7g
7h
7j
7k
7m

PLATE 6


SOC.-SEAB. VIOLET GROVE "7-6
6-7-48-7 W5M
KB 2896
IMP. CYNTHIA "14-28
14-28-52-11 W5M.
KB 2940
IMP. CHRISTMAS CK. "11-10
11-10-62-10 W5M
KB 2817
IMP. JARV
KB 20
1
2
3
4
35 miles
57 miles
54 miles
upper Mannville group
lower Mannville group
"Glauconitic" Sandstone member
"Calcareous" member
Ellerslie member
Depth 6752
Depth 6743
Depth 4908
Depth 2853
DATUM: Top of Ellerslie member
Detrital zone
Pre-Cretaceous
possible pre-Mannville contact
unconformity
Detrital
zone
possible barrier
Spontane
SP



LEGEND

- Sandstone
- Siltstone
- Shale
- Limestone
- Dolomite
- Coal
- Conglomerate

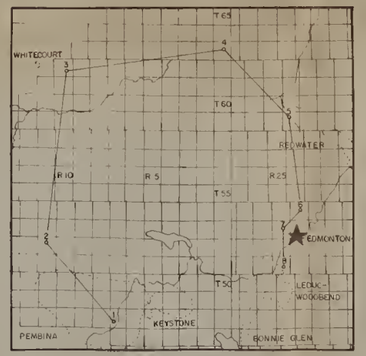
ELECTRIC LOG

Spontaneous Potential — Resistivity

S.P Curve — Normal Curve

Cored Interval

LINE OF CROSS-SECTION



SCALE 1" = 32 miles

FIGURE 4

STRATIGRAPHIC CROSS-SECTION

SHOWING

The Lower Mannville Group of the Present Area

AND

A Correlation with Studied Logs to the East, Badgley (1952), Glaister (1959), & Williams (1960)

Scale : Horizontal - Not to Scale
Vertical : 1" = 100 feet

FM